GUT BAY, KOOK, AND HOKTAHEEN LAKES

SUBSISTENCE SOCKEYE SALMON STOCK ASSESSMENT PROJECT

2001 ANNUAL REPORT

By

Jan Conitz
and
Margaret Cartwright

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Alaska Department of Fish and Game
Division of Commercial Fisheries
P.O. Box 240020
Douglas, Alaska 99824

This report has been prepared to assess project progress. Review comments have not been addressed in this report, but will be incorporated into the final report for this project.

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1 The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate timely reporting of recently collected information, reports in this series undergo only limited internal review and may contain preliminary data, this information may be subsequently finalized and published in the formal literature. Consequently, these reports should not be cited without prior approval of the author or the Division of Commercial Fisheries.

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PROJECT SPONSORSHIP

The Federal Subsistence Board, managed by US Fish and Wildlife Service – Office of Subsistence Management, approved the Gut, Kook and Hokthaheen Lakes Sockeye Salmon Stock Assessment Project (Study Number FIS01-125). The project was funded by the US Forest Service, and is a cooperative project between the US Forest Service (USFS), the Alaska Department of Fish and Game (ADFG), and the Klawock Cooperative Association (KCA). This annual report partially fulfills contract obligations for Sikes Act Contract (43-0109-1-0114 and 43-0109-1-0013).

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ABSTRACT

Sockeye salmon (*Oncorhynchus nerka*) returning to Gut Bay, Kook, and Hoktaheen lakes are an important subsistence resource for the people of Kake, Angoon, and Hoonah. The Gut Bay, Kook, and Hoktaheen Lakes Sockeye Salmon Stock Assessment Project was initiated because of concerns about the potential increase in harvest of sockeye salmon returning to these lake systems. The project evaluates sockeye salmon production at various life stages and assesses lake productivity. This annual report summarizes work conducted during the first year of project operations, 2001.

Portions of the spawning sockeye salmon populations in Gut Bay Lake, Kook Lake, and Hoktaheen Lake were estimated through observer counts and mark-recapture studies; age, length, and sex composition of these populations were estimated using standard measurements and scale sampling and analysis. Sockeye salmon fry populations in each lake were estimated using hydroacoustic and trawl sampling. Baseline information was collected on the physical characteristics and productivity of lake rearing habitat in each system using standard limnological sampling procedures. Gut Bay Lake appeared to have low spawning escapement, but observer counts increased late in the season. By contrast, sockeye salmon fry density was high in Gut Bay Lake, although this result should be interpreted cautiously until more data are collected. Zooplankton density, body size, and biomass were low in Gut Bay Lake. Kook Lake also appeared to have low escapement, with a mark-recapture estimate of 378 (95% CI 254 – 702). Logs and other large woody debris had built up to form a barrier in the Kook Lake outlet stream; this was cleared in August prior to any observed escapement into the lake. The sockeye salmon fry population in Kook Lake was very low, perhaps as a result of the partial barrier being in place for many years. Water quality values and secondary production in Kook Lake were average compared to similar organically stained, sockeye salmon rearing lakes in Southeast Alaska, and indicate the lake may be able to support a larger sockeye salmon fry population. In Hoktaheen Lake, a spawning population of 745 (95% CI 617 – 967) sockeye salmon was estimated in the single major inlet stream; sockeye salmon were also observed spawning in the outlet stream but not included in the mark-recapture study. The fry population density was relatively high, and zooplankton density was also high, particularly in the larger cladocerans preferred by sockeye salmon fry.

This year’s results provide the foundation for a multiple-year study to assess the health of the sockeye salmon stock in Gut Bay, Kook, and Hoktaheen lakes and to set a range of escapement goals capable of sustaining these populations for many generations.

INTRODUCTION

Gut Bay Lake (ADF&G stream no.109-20-007/008), Kook Lake (ADF&G stream no. 112-12-026), and Hoktaheen Lake (ADF&G stream no. 113-94-003) have been important sockeye salmon resources for the people of Kake, Angoon, Hoonah, and other Southeast Alaska Tlingit communities since time immemorial. They continue to be important subsistence systems with moderate annual sockeye salmon harvests. In recent years, there has been concern about increased fishing pressure and declines in sockeye salmon harvests, harvest opportunities, and escapement in these traditional subsistence areas.

Gut Bay was in the traditional territory of both the Kake and Angoon people. It was reported to have belonged at one time to the Sukteeneidi clan of Kake, and there were cabins and smokehouses in Gut Bay until recent historic times (Goldschmidt et al. 1998). In former times, the people of Kake were spread out among several villages on Kuiu, Kupreanof, Baranof, and Admiralty islands and the mainland, until a government school was opened in the present-day Kake village in the early 1900s; for this reason, their traditional harvest areas are relatively far from the present-day Kake village. From the early 1900s until the 1950s, Kake people often fished and hunted at Gut Bay and other locations along south Baranof Island while traveling in larger boats to and from commercial fishing grounds in the vicinity of Port Alexander. Although Kake residents no longer fish out of Port Alexander, they still use Gut Bay frequently for subsistence harvest of deer and marine intertidal resources, as well as salmon, crossing Chatham Straits in skiffs or small cabin cruisers. In recent times, over 50% of Kake households have reported using Gut Bay for subsistence hunting and fishing; it, along with Pillar Bay and Falls Lake, is among the most commonly used subsistence areas for the village of Kake. The majority of Kake households continue to harvest salmon for subsistence, and share the harvest widely within the community. (Firman and Bosworth 1990). Gut Bay is in the federal customary and traditional use area for the village of Kake (federal subsistence fishing regulations, 2002).

Basket Bay belonged to a group of the Angoon Deisheetan, known as the Kak'w.wedi, who had a tribal house there. People continued to live there until the early 1900s (de Laguna 1960; Goldschmidt and Haas 1946). Between 1957 and 1984 an average of 21% of Angoon households used Basket Bay for subsistence. Angoon harvesters claimed that the Kook Lake sockeye salmon were larger than those from their other traditional sources, Sitkoh and Kanalku lakes. In addition to salmon fishing, Angoon residents have used the area for seal and deer hunting, and for gathering shellfish and other resources (George and Bosworth 1988). People from Hoonah, Tenakee, and Juneau also use Kook Lake for subsistence and personal use sockeye salmon fishing.

Hoktaheen Lake was within the traditional hunting and fishing areas of the Hoonah people, who claimed all of Yakobi Island as well as Lisianski Strait and Lisianski Inlet. Hoktaheen probably belonged to the Takdeintaan clan (Goldschmidt and Haas 1946, Goldschmidt et al. 1998). Within recent memory, there were summer camps and smokehouses at Hoktaheen, and people would travel there from Hoonah every summer to gather seaweed and fish for sockeye salmon. At present, most subsistence users make day trips to the area during periods of good weather, coming from Hoonah as well as Pelican and Elfin Cove.

Subsistence harvests in these systems are currently estimated from information recorded by permit holders on their permits and returned annually to ADF&G. The system is voluntary and there is no independent verification of the number of fish harvested. According to subsistence permit data an average of 452 sockeye salmon were harvested annually from Gut Bay between 1985–2000 on an average of 36 permits, with an average catch per permit of 13 fish (Appendix A.1). There are no clear trends in the reported subsistence harvest pattern for Gut Bay. At Basket Bay, subsistence sockeye harvests of over 1,500 annually were recorded from 1981 to 1984, prior to the current system of collecting data from permits. Annual harvest and effort have fallen sharply, according to subsistence permit data, from a high harvest of 1,427 sockeye salmon on 78 permits in 1986, to an average of 367 sockeye salmon on an average of 25 permits since 1987 (Appendix A.2). Whether these changes resulted from declining sockeye salmon returns to Basket Bay, or some other, possibly socioeconomic factor, is unknown. The total subsistence sockeye salmon harvest and the number of permits issued for Hoktaheen rose steeply from 1990 through 1997 and has declined in recent years (Appendix A.3). An average of 30 permit holders harvested a mean of 715 sockeye salmon from 1988 to the present. The peak harvest for this time period was 1,720 sockeye salmon in 1997 with 59 permits returned. The total sockeye salmon harvest for the two most recent years was below average, approximately 600 fish. The public has complained recently about aggressive fishing and possible overharvest in the Hoktaheen subsistence and personal use fisheries. Sockeye salmon school around the mouth of the stream and wait for higher water levels before ascending to the lake, making these fish vulnerable to the fisheries for longer periods of time during dry weather (B. Davidson, ADF&G Sitka area, personal communication, 2002). The Fisheries Resource Monitoring Program is currently funding a cooperative project between the ADF&G Division of Subsistence and the Organized Village of Kake to document the historic and contemporary subsistence sockeye salmon harvests and use in Gut Bay, Falls Lake, and Pillar Bay. This project is scheduled for completion in 2002 (Larson 2001).

Sport fish harvests account for a small number of sockeye salmon returning to Gut Bay. Combined data from the area, including Falls Lake and Gut Bay, show a maximum possible freshwater harvest of 222 fish and a maximum saltwater harvest of 825 fish in 1999. However, it is likely these systems contributed fewer fish. Annual average marine harvests of 20 sockeye salmon were recorded in charter vessel logbooks from the statistical Subdistrict 109-20 containing Falls Lake and Gut Bay. No freshwater harvest was reported for Gut Bay in Tongass National Forest outfitter guide logbooks (Larson 2001). The U.S. Forest Service maintains a recreational cabin on Kook Lake, making it a popular sport fishing destination. ADF&G sport fish surveys indicate high effort and occasionally very large catches of sockeye salmon in the lake (Appendix A.4). The area around Hoktaheen Cove has become increasingly popular for sport fishing (Appendix A.4). Sport fishers target mainly chinook and coho salmon and halibut, but sockeye salmon are caught incidentally or sometimes targeted (ADF&G database; R. Walker, personal communication, 2000).

Historic commercial fisheries between 1892 and 1927 targeted sockeye salmon at all three systems (Rich and Ball 1933) (Appendix A.5). Harvest records from Gut Bay show much higher numbers of sockeye salmon than what is indicated by current escapement and subsistence harvest data, although some of these numbers may reflect catches of sockeye salmon from sources other than Gut Bay. Fishing effort was intense in southern Chatham between 1910 and 1920, and fish traps were used during this period. However, Gut Bay and other locations along the west side of Chatham Strait were not considered to be large or important fisheries compared to those on the east side, such as Bay of Pillars and Tebenkof Bay, where sockeye salmon catches were regularly in tens of thousands. Gut Bay was closed to commercial fishing in 1926, along with most other sockeye salmon systems in Chatham Strait. Data from Basket Bay are sketchy, but in general, show huge sockeye salmon catches during the first ten years of exploitation, and a severe drop in numbers after this initial exploitation. The earliest record of commercial fishing in the area was from Sitkoh Bay in 1890. Since sockeye salmon systems were targeted exclusively during this time, it was likely that nearby Basket Bay was also fished commercially from the beginning of this period. The first cannery in the area was built in 1889 at Pavlof Harbor. However, this cannery was moved south to the Bay of Pillars in the following year. Beginning in 1924, conservation closures were implemented in Basket Bay and other bays along Chatham Strait. For Hoktaheen Cove, there is a fairly complete record of commercial sockeye catches in the early 1900s, showing the typical pattern of high exploitation for about ten years followed by a sharp decline. It was assumed that this sockeye run was over-fished to depletion (Rich and Ball 1933).

Currently, there are no commercial fisheries in the terminal areas of these systems, but purse seine fisheries take unknown numbers of sockeye salmon incidentally. The purse seine fishery operating in Chatham Strait outside of Gut Bay and Falls Lake is the largest user of sockeye salmon in this area. Stocks from specific systems cannot be separately identified in the commercial harvest record, but there has been an increase in total numbers of sockeye salmon harvested in recent years in the areas nearest to Falls Lake and Gut Bay, as well as along the east side of Chatham Strait (Larson 2001). The average annual sockeye harvest for the Falls and Gut Bay areas (Subdistricts 109-20, 112-11, 112-21, and 112-22) has increased from 1,113 sockeye salmon in the 1970s to 2,508 in the 1980s to 11,146 in the 1990s (Appendix A.6). Most of the increase in harvest is due to an increase in sockeye salmon landed as bycatch in the hatchery chum salmon fishery at Hidden Falls (Larson 2001). Likewise, the commercial purse seine fishery operating in upper Chatham Strait takes some unknown number of Basket Bay sockeye salmon, and ADF&G has taken management actions on several occasions to reduce harvests of Kook Lake sockeye salmon (ADF&G Emergency Orders). In 1994, the purse seine fishery was closed along the Basket Bay shoreline in order to protect Kook Lake sockeye salmon and there have been area closures in the purse seine fishery in the vicinity of Basket Bay during several years. Sport and subsistence fishing in Basket Bay were closed by emergency orders in July of 1985, 1990, and 1994. There are no seine fisheries operating in the immediate vicinity of Hoktaheen Cove, but fisheries at the mouth of Lisianski Inlet, in Icy Straits, and southward along the outside Chichagof Island coast may incidentally catch some sockeye salmon returning to Hoktaheen Lake.

Sockeye salmon stock assessment and lake productivity data are limited in these systems. While aerial surveys have been conducted in most years since 1960, these counts do not give a reliable estimate of sockeye salmon populations due to variation in visibility, timing, and observers (Jones and McPherson 1997, Jones et al. 1998). Commercial fishery management biologists usually fly these surveys opportunistically when they are conducting pink salmon or other aerial surveys in a nearby areas, and do not attempt to estimate total or peak escapement of sockeye salmon into specific systems. The Sitka area managers have expressed concern about sockeye salmon escapement at Gut Bay during the last two decades, based on low aerial survey numbers (Appendix A.7; D. Gordon, ADF&G, personal communication, 2002). At Kook Lake, overhanging forest canopy hides the view of the inlet streams and the outlet stream flows through underground caves, but the aerial surveys have been supplemented in some years with on-the-ground surveys (Appendix A.8). The only data available for the Hoktaheen system is from sporadic aerial surveys; there were no surveys during the 1980s and most of the 1990s (Appendix A.9). Since 1997 counts at Hoktaheen have been very low.

For Kook Lake, additional stock assessment and lake productivity data from a cooperative project between ADF&G and the USFS in the 1990s are available. An adult weir was operated in 1994 and 1995 with weir counts of 1,800 and 5,800 sockeye salmon, respectively. An ADF&G crew sampled the spawning population in Kook in 1983, 1984, 1985, 1987, 1994, and 1995. The dominant age class overall of sockeye salmon estimated in several years since 1982 was age-1.3, with age-1.2 dominant in two years (Appendix B.4). The sockeye fry population was estimated in the fall of 1994 and 1995 in Kook Lake using hydroacoustic and tow net sampling. In the spring of those years, the population of emigrating sockeye salmon smolt was estimated using weirs (Table 1). Limnological studies conducted in 1992, 1994, and 1995 showed that Kook Lake is an organically stained, oligotrophic lake with low phosphorus concentrations (spring total phosphorus 3.4 $\mu g\ L^{-1}$) and rapid flushing (water residence time 0.70 yrs), and only moderate secondary productivity relative to other sockeye salmon nursery lakes in Southeast Alaska (average seasonal mean density of macrozooplankton 76,218 m^{-2}). The largest component of both density and biomass was the copepod *Cyclops* sp., followed by cladocerans *Bosmina* sp. and *Daphnia longiremus*. Kook Lake is dimictic, becoming thermally stratified in the summer, and had an average euphotic zone depth of 6.9 m in 1995 (Barto and Cook 1995, 1997).

Table 1. Fall sockeye fry population estimates and spring emigrating smolt estimates for Kook Lake, 1994 and 1995 (Barto and Cook 1997).

Year	Total Fall Fry	Total Smolt
1994	85,629	11,654
1995	50,059	7,994

Fishery managers and biologists at ADF&G and the U.S. Forest Service expressed concern about the Kook Lake sockeye salmon run when no sockeye salmon were observed in aerial or ground surveys during July 2001. In response to these concerns, the Kook Lake outlet stream was cleared of large deadfall and other debris obstructing the entrances of the caves through which it passes by a crew of U.S.

Forest Service and Angoon Community Association employees on 17 August. At the time of the stream clearing, about 1,000 sockeye salmon were schooled at the stream mouth and about 100 were in the stream; just a few of these fish were upstream of the obstructions (B. VanAlen, ADF&G, personal communication, 2001). The partial barriers may have impeded sockeye salmon migration into Kook Lake for the past several years. Clearing the barriers probably enabled more sockeye salmon to reach Kook Lake in 2001, but it may have been too late to benefit the entire run. The outlet stream will be monitored and cleared as necessary by field crews in 2002 and future years.

The Gut Bay, Kook, and Hoktaheen Sockeye Salmon Project is one of eight new projects, initiated in 2001 and funded through the Federal Subsistence Fisheries Resource Monitoring Program, to assess significant subsistence sockeye salmon runs in Southeast Alaska. The project will collect escapement and lake ecology data at each system to support long-term escapement goals that incorporate lake productivity modeling. The study plan includes an assessment of the lake's physical characteristics, which support primary production, and the secondary production of its zooplankton populations. Zooplankton are the main food source for sockeye salmon, and cladocerans are their preferred food within the zooplankton community. By estimating the biomass and number of zooplankton by species, we can evaluate whether food is a limiting factor for juvenile sockeye salmon in any of the sockeye salmon rearing lakes. The species composition over the season and between years may provide insight into how the zooplankton community responds to different fry densities and adult escapement levels. Juvenile population parameters, including density, size, and age composition, are indicators of sockeye salmon response to conditions within the lake and will be estimated. The escapement and age-composition data we are collecting, combined with subsistence permit harvest reports, will enable us to estimate spawner-recruit relationships. This report summarizes the sockeye salmon stock assessment data collected in 2001, the first year of this project.

OBJECTIVES

1) Index the annual sockeye salmon escapement into each lake with a precision of +/- 15%, with 90% confidence using a mark-recapture program.

2) Estimate the age, length, weight, and sex composition of sockeye salmon in indexing samples from each lake such that these estimates are within 5%, 95% of the time.

3) Collect baseline data on in-lake productivity of each lake using established ADF&G limnological sampling procedures, which may include water chemistry, zooplankton sampling, hydroacoustic fry assessments, and smolt sampling.

Changes to Objectives

The precision estimates for the population variables to be estimated were incorrectly stated in the original objectives listed above. Objectives 1 and 2 will therefore be changed for the subsequent years of the project as follows:

1) Index or estimate the annual sockeye escapement into each lake, so that the estimated coefficient of variation is less than 15%.

2) Estimate the age, length, weight, and sex composition of the sockeye salmon in the mark-recapture samples from each lake, so that the estimated coefficient of variation is less than 5%.

A 95% confidence interval will also be reported for these population estimates, where appropriate.

METHODS

Study Sites

Gut Bay Lake

Gut Bay Lake (N 56°42.97', W 134°42.15') is a small lake draining into the head of Gut Bay, a steep fiord on the southeastern side of Baranof Island about 80 km from the village of Kake. The lake drains a watershed area of about 17 km^2 and is at 18 m in elevation. The lake has a surface area of 36 hectares, a mean depth of about 16 m, and a maximum depth of about 25 m (Figure 1). The outlet stream is about 2 km long. Sockeye salmon (*Oncorhynchus nerka*) constitute the major spawning population in this system, which also has minor runs of pink (*O. gorbuscha*), coho (*O. kisutch*), and chum salmon (*O. keta*).

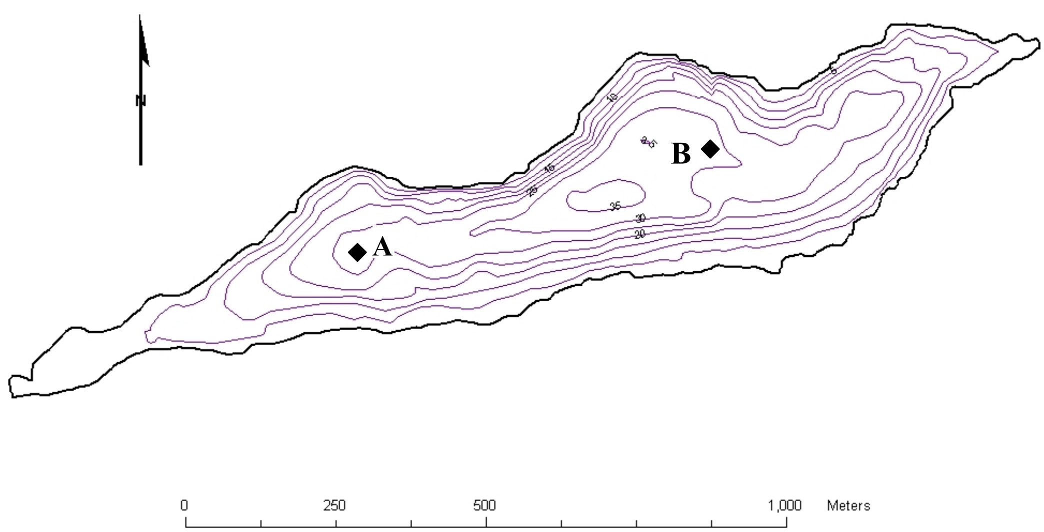

Figure 1. Bathymetric map of Gut Bay Lake, showing 5 m depth contours and two fixed sampling stations.

Kook Lake

Kook Lake (N 57°39.92', W 134°58.97') is on the east side of Chichagof Island, about 26 km northwest of Angoon. The total drainage area is about 54 km^2 and there are two main inlet streams entering the southwest end of the lake. The lake lies at an elevation of about 123 m, and has a 2 km outlet stream that flows into Basket Bay on Chatham Strait. The outlet, Kook Creek, passes through three natural caves, each about 150-300 m long. Kook Lake has a surface area of about 240 ha, a mean depth of 30 m, and a maximum depth of 44 m (Fig. 2). In addition to sockeye salmon, the lake supports runs of coho, chum, and pink salmon; resident fish include Dolly Varden char (*Salvelinus malma*), cutthroat trout (*O. clarki*), threespine stickleback (*Gasterosteus aculeatus*), and sculpin (*Cottus* sp.). The Kook Lake watershed is extensively clearcut, and crossed by a logging road system, which connects with the Corner Bay logging camp in Tenakee Inlet.

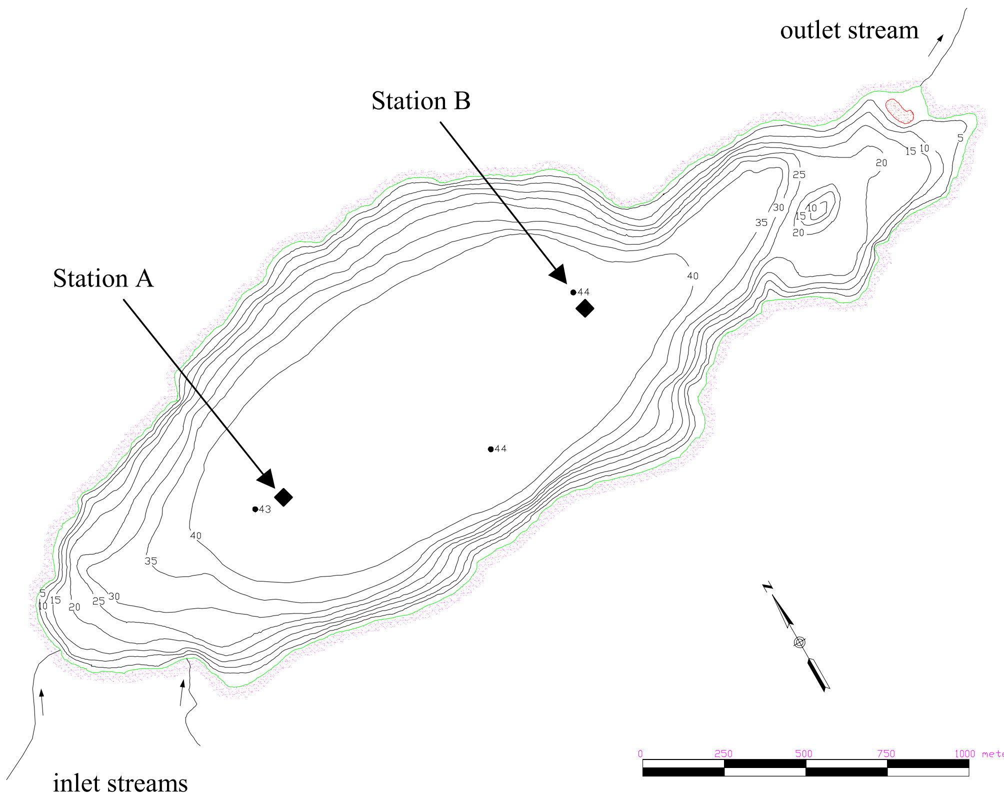

Figure 2. Bathymetric map of Kook Lake, showing 5 m depth contours and two fixed sampling stations.

Hoktaheen Lake

Hoktaheen Lake (58°03.23' N., 136°30.45' W.) is located on the northwest corner of Yakobi Island, about 25 km from the community of Pelican. The lake is at about 40 m in elevation and drains a watershed area of about 20 km^2. It has a surface area of 67 hectares, an average depth of about 20 m, and a maximum depth of about 40 m (Figure 3). The outlet stream connects Hoktaheen Lake with another smaller lake about 1 km downstream; from the lower lake, the outlet stream is about 5 km, draining into Hoktaheen Cove on the Gulf of Alaska. There is no record of fish other than sockeye salmon ascending into the lake, but large numbers of pink salmon spawn at the mouth of the outlet stream, and small numbers of coho and chum salmon are caught incidentally in the subsistence fishery in Hoktaheen Cove.

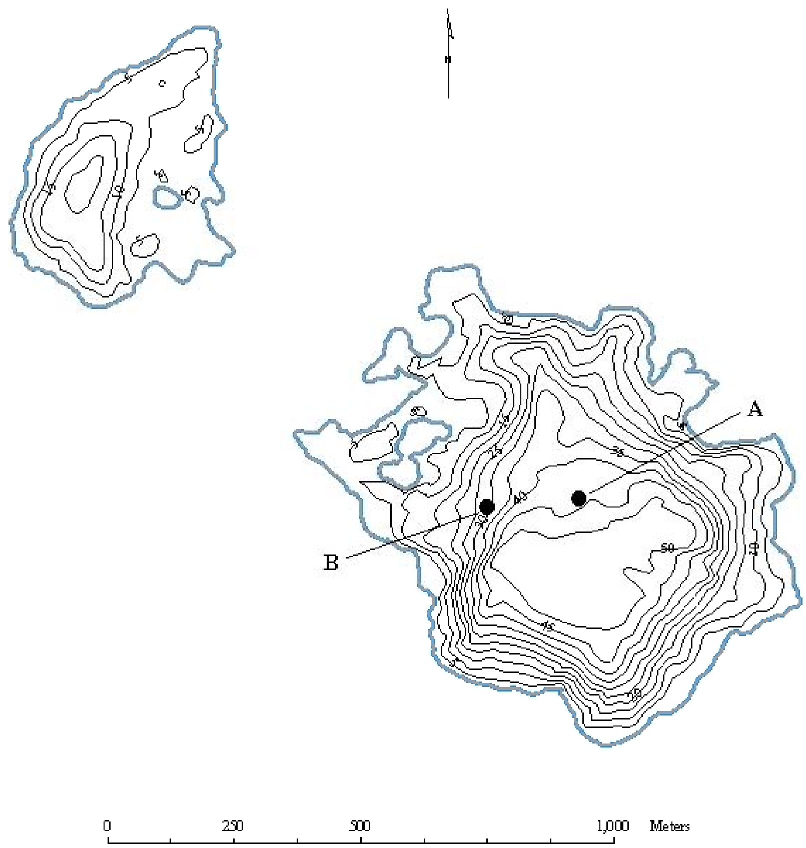

Figure 3. Bathymetric map of Hoktaheen Lake, showing 5 m depth contours and two fixed sampling stations.

Sockeye Fry Population Assessment

The distribution and abundance of sockeye fry were estimated by hydroacoustic and mid-water trawl sampling. Each lake was divided into sampling areas based on surface area for the hydroacoustic portion of the survey. Gut Lake was divided into six sampling areas, Hoktaheen into four sample areas, and Kook into seven sample areas. Prior to conducting a survey, one orthogonal transect was randomly chosen within each sampling area to survey. These cross-lake transects started and ended at a depth of 10 m and each transect was surveyed twice to get a repeated measure. Sampling was conducted in the darkest part of the night. A constant boat speed of about 2.0 m · sec^{-1} was attempted for all transects. The acoustic equipment consisted of a Biosonics[2] DT-4000™ scientific echosounder2 (420 kHz, 6° single beam transducer) and Biosonics Visual Acquisition© version 4.0.2 software was used to record the data. Ping rate was set at 5 pings · sec^{-1} and pulse width at 0.4 ms. A target strength of –50 dB to –68 dB was used to represent fish within the size range of juvenile sockeye salmon and other small pelagic fish. Data were analyzed using Biosonics Visual Analyzer© version 4.0.2 software. Echo integration was used to generate a fish density (fish · m^{-2}) for each of the sample areas (MacLennand and Simmonds 1992). A population estimate for each of the sample areas was calculated as the product of fish density and the surface area of each of the sample areas. Summing each sampling area population estimate generated a total population estimate for the lake. A second estimate was calculated using the repeated measure of each transect. The average between these two estimates was used as the total population estimate for each lake. A variance around the mean estimate was not possible because the survey was a repeated measures design instead of a true replicate design. We are revising our study design for hydroacoustic survey in accordance with a replicate sample design and will report a variance in the future.

Trawl sampling was conducted in conjunction with hydroacoustic surveys to determine the species composition of targets. A 2 m × 2 m elongated trawl net was used for pelagic fish sampling. Trawl depths and duration were determined by fish densities and distributions observed during the hydroacoustic survey. All captured fish were euthanized with MS-222 and preserved in 90% ethanol. In the laboratory, fish were soaked in water for 60 minutes before sampling. The snout-fork length was measured to the nearest millimeter (mm) and weight was measured to the nearest tenth gram (0.1g) on each fish. All sockeye salmon fry under 50 mm were assumed to be age-0. Scales were collected from fish over 50 mm for further age analysis. Sockeye salmon fry scale patterns were examined through a Carton microscope with a video monitor and aged using methods outlined in Mosher 1968. Two trained technicians independently aged each sample. The results of each independent scale ageing were compared. In instances of discrepancy between the two age determinations, a third independent examination was conducted.

Adult Sockeye Salmon Escapement Estimates

Mark-Recapture and Visual Survey

We observed that sockeye salmon at Gut Bay and Kook lakes were beach spawners. At Hoktaheen, the majority of fish were inlet stream spawners but some sockeye salmon were also observed spawning at the head of the outlet stream, just below the lake, late in the season. Four trips were scheduled to each study site to conduct lake surveys and mark-recapture studies. However, the first scheduled surveys and mark-recapture events were missed during the 2001 season due to poor weather and hazardous flying conditions into these lakes. Actual sampling schedules were as follows:

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[2] Product names used in this publication are included for scientific completeness but do not constitute product endorsement.

Gut Bay Lake	15 September	survey only
	1 October	survey only
	23 October	survey only
Kook Lake	10 September	survey and mark-recapture
	25 September	survey and mark-recapture
	10 October	survey and mark-recapture
Hoktaheen Lake	3 September	survey and mark-recapture
	20 September	survey and mark-recapture
	2 October	survey only

At the beginning of each trip, the numbers of spawners in defined shoreline strata around the lake were estimated to provide an escapement index and describe the distribution of spawners. At Gut Bay Lake, only visual counts around the perimeter of the lake were completed during each trip. At Kook Lake, a mark-recapture index area was selected where the majority of the fish were spawning, and the boundaries were recorded using Global Positioning Satellite (GPS). At Hoktaheen Lake, escapement was estimated by visual counts in the main inlet stream, as well as along the lake shoreline, and the mark-recapture study was conducted in the inlet stream. The mark-recapture studies were conducted only within these defined areas during subsequent trips.

Beach Spawning Population

The study design for the beach spawning population at Kook Lake consisted of two sampling stages: 1) a two-sample Petersen estimate for each trip (Seber 1982), and 2) a multiple trip estimate using a modified form of the Jolly-Seber method for multiple mark-recaptures in an open population (Seber 1982; Cook 1998). In the first stage, fish were marked on one day and examined for marks the next day; simple Petersen population estimates were generated from these data (Seber 1982). In the second stage, fish caught on both days of a given trip were marked with a unique mark for that trip, and in subsequent trips, recaptures of these marks were recorded. The sampling across trips used the first stage Petersen estimates to generate a population estimate within the index area for the entire season. The resulting population estimate for the index area was then expanded to an escapement estimate for the entire lake or stream, based upon the visual survey counts. The whole lake estimates were considered minimum escapement estimates because we assumed that we were unable to observe all spawners present.

A beach seine 20 m long and 4 m deep was used to surround sockeye salmon, pulled by a small skiff with outboard motor and crewmembers on foot. All sockeye salmon caught were first inspected for previous marks, then marked with an opercular punch or pattern of punches indicating the trip and day number, and released with a minimum of stress. The total sample size, the number of new fish marked, and the number of recaptured fish with each type of mark were recorded. Biological samples and measurements were taken from a subset of these sockeye salmon for age classification.

Stream Spawning Population

At Hoktaheen Lake, a stratified, two-sample mark-recapture procedure was used to estimate escapement in the inlet stream; due to circumstances, there were only two partial marking and two partial recapture strata and they were pooled (Arnason et al. 1995). In the first samples (marking phase), sockeye salmon were caught with a beach seine or dip net at the mouth of the inlet stream, and marked with an opercular punch to indicate the trip (stratum) number. In the second samples (recapture phase), live and dead fish were examined for marks; the numbers of marked fish from each stratum and the number of unmarked fish were recorded. A second mark was given to all fish in the second sample to prevent re-counting. The recapture phase was to take place upstream, but recaptures were also recorded at the mouth of the stream during the second day of marking.

Data Analysis

Beach spawning populations: The visual counts from each stratum were averaged across all observers, and the average counts from all strata inside and all strata outside the index area were summed. The number of observers varied from three to five. A bootstrap procedure was used to estimate the variance of counts between observers (Xinxian Zhang, ADF&G, personal communication, 2001).

Chapman's form of the Petersen mark-recapture estimate and variance was used (Seber 1982, p. 60) for the first stage point population estimates within the index area. Confidence intervals for these estimators were estimated using the criteria given in Seber (1982, p. 63), according to sample size and marking fraction. If the criteria were met, Seber's eq. 3.4 was used; otherwise, the confidence interval bounds were found from Table 41 in Pearson and Hartley (1966).

In the second stage, the point population estimates, N^*_i, were used in a Jolly-Seber multiple mark-recapture estimator, in place of the derived parameter estimating the number of animals alive in the system at each sampling occasion. The N^*_i were also used in the estimation of two other parameters, B_i and M_i, below (Schwarz et al. 1993; Cook 1998; J. Blick, ADF&G, personal communication, 1998). Given s sampling occasions,

N^*_i = number of fish alive in the system at sampling occasion i (the Chapman-Peterson point population estimates from the first stage),

n_i = number of unmarked fish and fish marked on previous trips, caught at sampling occasion i,

m_i = number of fish marked on previous trips, caught at sampling occasion i,

M_i = number of marked fish alive at time i,

ϕ_i = probability that a fish alive at time i is also alive at time $i+1$ (i.e. the survival rate),

Bi = number of fish that enter the system after occasion i and are still alive at time i+1 (i.e. immigration),

B^*_i = number of animals that enter the system after occasion i, but before occasion $i+1$,

N = total number of animals that enter the system before the last sampling occasion.

The specific intermediate estimates are:

$M_i = m_i N^*_i / n_i,$

$\phi_i = M_{i+1}/(M_i - m_i + n_i),$

$B_i = N^*_{i+1} - \phi_i N^*_i.$

B^*_i *(for* $1 < i < s-1) = B_i log(\phi_i)/(\phi_i - 1)$, where recruitment and mortality are assumed to be uniform between times i and i+1.

Because B_0, B_1, and B_{s-1} are not uniquely estimable, B_{s-1} was set to zero, assuming the sampling extended to the point where recruitment was virtually ended, and $B^*_0 + B^*_1$ was estimated by $N_2 log(\phi)/(\phi - 1)$. The total abundance N was then estimated as,

$N = \Sigma B^*_i$. (Schwarz et al. 1993; Cook 1998; J. Blick, ADF&G, personal communication 1998).

A bootstrap method was used to estimate the confidence interval for this estimator. This was based on two random variables: the number of marked fish caught in the second sample of the first stage mark-recapture as a random variable with hypergeometric distribution, and the number of marked fish caught in the second stage mark-recapture as a random variable with normal distribution (X. Zhang, ADF&G, personal communication 2002).

Linear regression was used to compare mark-recapture escapement estimates to visual counts within the index areas across all lakes and sampling dates for the 2001 season (X.Zhang, ADF&G, personal communication, 2002). Mark-recapture and observer count data from four lakes in the Chatham Strait region (Kook, Sitkoh, Kanalku, and Falls Lakes) were pooled since there were insufficient data from any one lake in this first sampling season with which to estimate a regression. The four lakes included in this regression had similar water color, shoreline characteristics, and spawning areas used by sockeye salmon. The slope obtained from the regression was 2.02 with an R^2 value of 0.94; this slope was used to predict escapement for the whole lake from the visual count for the whole lake.

Stream spawning populations: A "pooled Petersen" estimate was used in which all marking strata were combined into a single marking event and all recapture strata were combined into a single recapture event (Arnason et al. 1995). The total population and variance estimates were calculated using Chapman's modification (Seber 1982, p. 61). A 95% confidence interval for the number of recaptured fish was estimated using the normal approximation, and the corresponding confidence interval for the total population estimate was calculated from it (Seber 1982, p. 63).

Adult Sockeye Salmon Population Age and Size Distribution

The age composition for brood year analysis was determined from a set of scale samples and length measurements collected from mark-recapture samples during one or more trip to each system. The sample target number was 600 biological samples for each system. Three scales were taken from the preferred area of each fish (INPFC 1963), and prepared for analysis as described by Clutter and Whitesel (1956). Standard ADF&G procedures were followed in collecting the scales and recording data (ADF&G Staff 2001). Mid-eye to fork length was measured to the nearest millimeter (1 mm). All scale analysis was conducted at the ADF&G, Commercial Fisheries aging laboratory in Douglas, Alaska.

Limnology Sampling

Limnology sampling was scheduled for each lake at six-week intervals from mid-May through October, for a total of four sampling dates. Two stations were set up in each lake at the deepest part of the lake, separated as widely as possible at that depth. Physical data were taken only at one station. Zooplankton samples were collected from both stations on each sampling date.

Light

Measurements of underwater light penetration (footcandles) were recorded at 0.5 m intervals, from the surface to a depth equivalent to one percent of the subsurface light reading, using a Protomatic International Light submarine photometer. Vertical light extinction coefficients (K_d) were calculated as the slope of the light intensity (natural log of percent subsurface) versus depth. The euphotic zone depth (EZD) is defined as the depth to which one percent of the subsurface light, as phototsynthetically available radiation (400–700nm), penetrates the lake surface (Schindler 1971), and was calculated from the equation, EZD = 4.6205/ K_d (Kirk 1994).

Temperature and Dissolved Oxygen

Temperature and dissolved oxygen (DO) profiles were measured with a Yellow Springs Instruments Model 58 DO meter and probe, calibrated each sampling trip with a 60 ml Winkler field titration (Koenings et al. 1987). Relative (%) and absolute (mg L^{-1}) DO values were recorded; temperature values were in ºC. Measurements were made at 1 m intervals to the first 10 m or the lower boundary of the thermocline (defined as the depth at which the change in temperature decreases to less than 1ºC per meter), and thereafter at 5 m intervals to within 2 m of the bottom (or 50 m).

Secondary Production

Zooplankton samples were collected at two stations on each lake using a 0.5 m diameter, 153 um mesh, 1:3 conical net. Vertical zooplankton tows were pulled from 2 m above the station depth at a constant speed of 0.5 m sec^{-1}. The net was rinsed prior to removing the organisms, and all specimens were preserved in neutralized 10% formalin (Koenings et al. 1987). Zooplankton samples were analyzed at the

ADF&G, Commercial Fisheries limnology laboratory in Soldotna, Alaska. Cladocerans and copepods were identified using the taxonomic keys of Brooks (1957), Pennak (1978), Wilson (1959), and Yeatman (1959). Zooplankton were enumerated from three separate 1 ml subsamples taken with a Hensen-Stemple pipette and placed in a 1 ml Sedgewich-Rafter counting chamber. Zooplankton body length was measured to the nearest 0.01 mm from at least 10 organisms of each species along a transect in each of the 1 ml subsamples using a calibrated ocular micrometer (Koenings et al. 1987). Zooplankton biomass was estimated using species-specific dry weight versus zooplankter length regression equations. The seasonal mean density and mean weighted length was used to calculate the seasonal zooplankton biomass (ZB) for each species. Marco-zooplankters were further separated by sexual maturity where ovigorous (egg bearing) zooplankters were also identified (Koenings et al. 1987).

RESULTS

Sockeye Fry Population Assessment

Hydroacoustic surveys were successfully completed in Gut Bay, Kook, and Hoktaheen lakes on 17 August, 10 July, and 18 September, respectively. Two mid-water tows were conducted in Gut Bay Lake, one at 10 m for 10 minutes and one at 7 m for 15 minutes. The fish counts recorded in the first and last transect on the repeated measure were highly suspect because the number of fish recorded was unreasonably inflated. Therefore, a single estimate for Gut Bay Lake is presented in this report. A total lake population of 87,00 sockeye salmon fry was estimated from the hydroacoustic survey and the estimated density of sockeye salmon fry in the lake was 0.32 fry · m^{-2} (Table 2). The bimodal length frequency distribution shows the two age classes (Figure 4). Two mid-water tows were conducted in Kook Lake, at 10 m and 7 m for 15 minutes each. The total lake population estimate was 60,000 sockeye salmon fry (range of repeated measure was 51,000 to 70,000 fry) and the estimated density was 0.026 fry · m^{-2} (range of repeated measure was 0.022 to 0.030 fry · m^{-2}). Only age-0 fish were present in the sample, ranging from 36–54 mm in length (Figure 5). In Hoktaheen Lake, mid-water tows were conducted at 8 m and 10 m for 20 minutes each. The total lake population estimate was 101,000 sockeye salmon fry (range of repeated measure was 86,000 to 115,000 fry) and the estimated density of sockeye salmon fry for the lake was 0.250 fry · m^{-2} (range of repeated measure was 0.214 to 0.287 fry · m^{-2}). The sockeye salmon fry length frequency distribution shows a dominant age-0 class with a small age-1 class (Figure 6).

Table 2. Size and age distribution of sockeye salmon fry and stickleback, estimated from midwater trawl samples and population estimates, based on hydroacoustic surveys with species and age apportionment, based on trawl samples, for Gut Bay, Kook, and Hoktaheen lakes, 2001.

Lake	Species	Age	Sample Size	Proportion of Total	Mean Length (mm) ± 1 SE	Mean Weight (g) ± 1 SE	Total Population
Gut Bay	Sockeye	0	51	75%	38.3 ± 1.1	0.62 ± 0.05	65,000
	Sockeye	1	17	25%	59.5 ± 0.8	2.11 ± 0.08	22,000
Kook	Sockeye	0	52	100%	42.9 ± 0.6	0.71 ± 0.03	61,000
Hoktaheen	Sockeye	0	217	96%	40.9 ± 0.3	0.54 ± 0.01	97,000
	Sockeye	1	9	4%	58.3 ± 1.1	1.64 ± 0.08	4,000

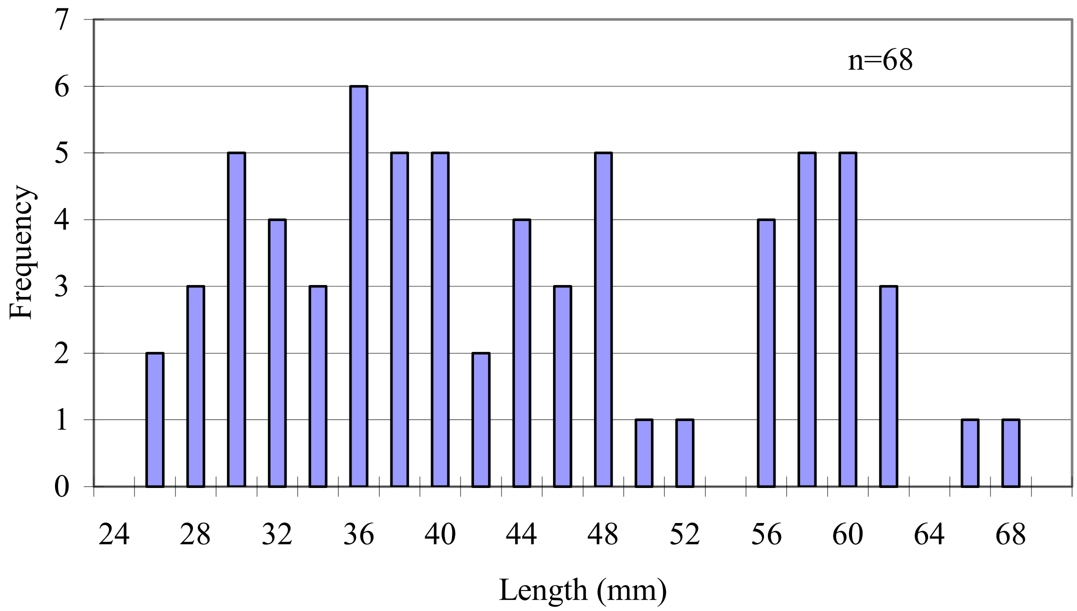

Figure 4. Length frequency distribution of sockeye salmon fry in Gut Bay Lake, 2001. All sockeye fry less than 50 mm long were assumed to be age-0; of those greater than 50 mm long, scale pattern analysis showed that four were age-0 and 17 were age-1.

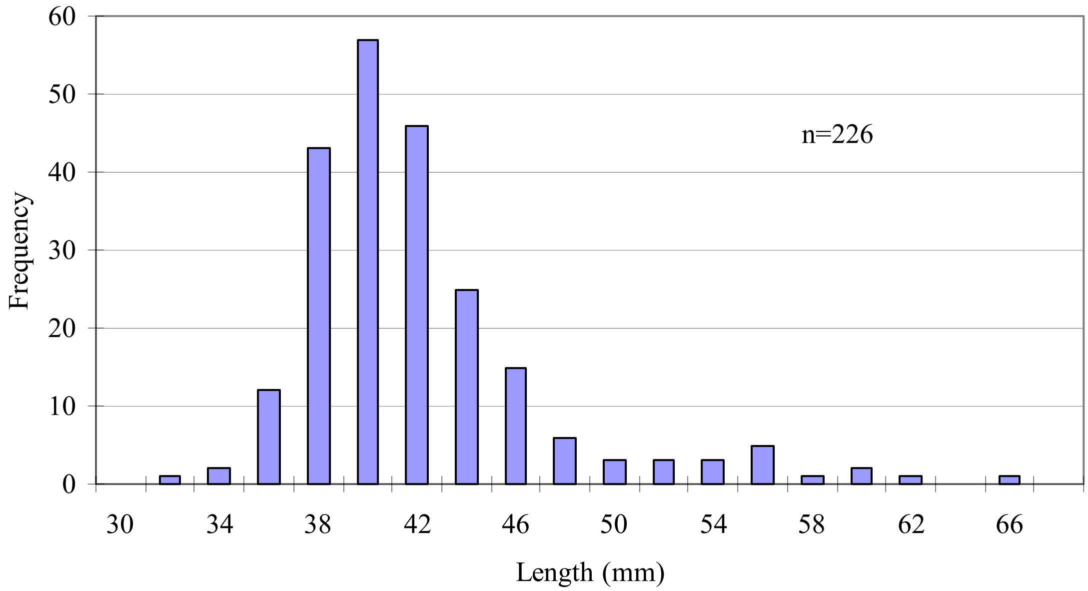

Figure 5. Length frequency distribution of sockeye salmon fry in Kook Lake, 2001. All sockeye fry less than 50 mm long were assumed to be age-0; of the four fish greater than 50 mm long, scale pattern analysis showed that all were age-0.

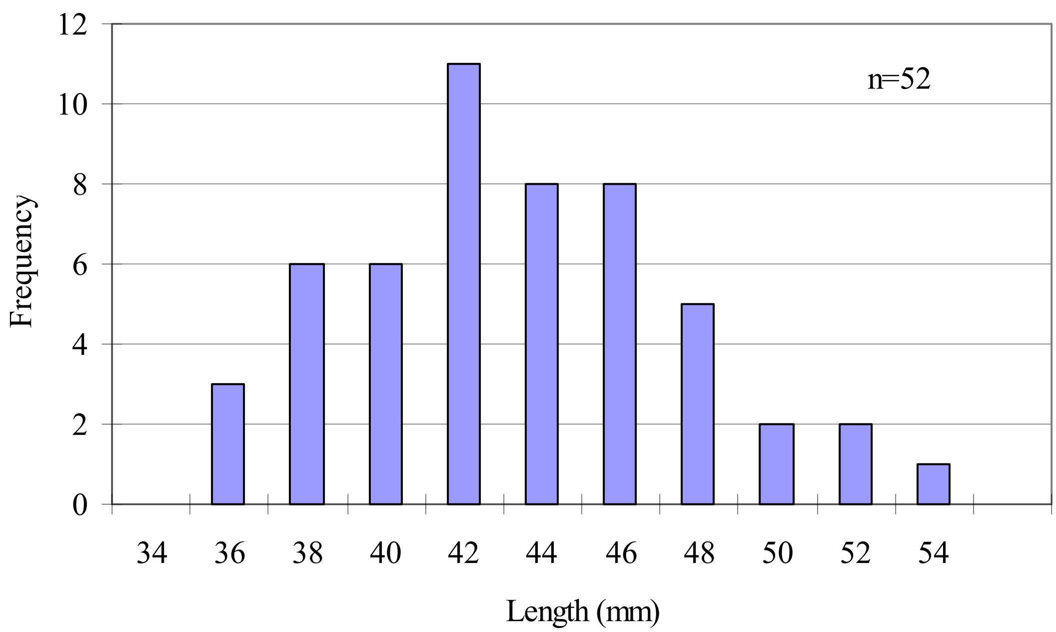

Figure 6. Length frequency distribution of sockeye salmon fry in Hoktaheen Lake, 2001. All sockeye fry less than 50 mm long were assumed to be age-0; of those fish greater than 50 mm long, scale pattern analysis showed that seven were age-0 and nine were age-1.

Mark-Recapture and Visual Survey

We had varying success in estimating escapements in the three systems. In Gut Bay Lake, the spawning sockeye salmon were dispersed among several areas around the lakeshore, making it difficult to select a single index area. Also, overhanging vegetation and large amounts of woody debris made beach seining difficult or impossible, so only visual surveys and no mark-recapture events were completed (Table 3). Two separate spawning areas constituted the index area in Kook Lake. As more sockeye salmon entered the spawning grounds, other spawning areas had higher concentrations of spawners than the original sites selected. However, the original index area was used throughout the season to maintain consistency across trips. Because few fish were present in Kook Lake, sample sizes were very small, and we were only able to complete three trips; consequently the confidence interval (CI) around the adult population estimate was large and precision was low (Table 3). The expanded, whole-lake estimate should be considered preliminary. The index area at Hoktaheen Lake was the largest inlet stream. Unfortunately, we were only able to visit this lake three times due to weather and grounding of the planes after 11 September. Spawning was completely finished in this stream by the last trip on 2 Oct., and only carcasses were observed, so a third mark-recapture event was not conducted. However, a moderate spawning population was observed in the top section of the outlet stream. These sockeye salmon were counted in the 20 Sept. and 2 Oct. surveys but were not sampled in any of the mark-recapture events. An expanded, whole lake escapement estimate was not possible for Hoktaheen Lake.

Table 3. Visual survey counts for the entire lake and within an index area defined for the mark-recapture study; mark-recapture study results and confidence interval estimates. Gut Bay, Kook, and Hoktaheen lakes, 2001.

Lake	Date	Visual Survey Entire Lake	Visual Survey Index Area	Peterson Estimate, Index Area (95% CI)
Gut Bay	9/15	38	na	na
	10/1	146	"	"
	10/23	193	"	"
Kook	9/10	265	25	30 (24, 42)
	9/25	124	43	114 (95, 150)
	10/10	28	14	11 (7, 60)
modified Jolly-Seber escapement estimate for index area[a]				**233** (182, 386)
expanded escapement estimate for whole lake[ab]				**378** (254, 702)
Hoktaheen	9/3	na	480	
	9/20	206	51	
	10/2	132	50 (carcasses only)	
	pooled Peterson escapement estimate for inlet stream[a]			**745** (617, 967)

[a] 95% confidence intervals are indicated.
[b] Expanded whole lake escapement estimates should be considered preliminary (see discussion section).

Adult Sockeye Salmon Population Age and Size Distribution

Scales, sex, and a snout-fork length were collected from sockeye salmon adults returning to Kook and Hoktaheen lakes. No biological samples were collected from the sockeye adults in Gut Bay Lake due to the difficulties in using seine nets in the nearshore area of this lake. Of the 38 total adult sockeye salmon scale samples analyzed from Kook Lake in 2001, 68% of the population was male (Table 4). The 1.2 age class was dominant class, 55.3% (*n*=21), followed by 36.8% (*n*=14) age 1.3 and 2 females were aged as 2.2 fish (Table 4). The mean length of age 1.2 fish was 497 mm compared to 551 mm for the 1.3 sockeye adults in Kook Lake (Table 5). Although the mean length was similar between the male and female sockeye salmon adults, the males had a wider range of lengths (SE=11) compared to females (SE=6; Table 5). A 258 mm fish aged as a 1.2 male is most likely a 1.1 jack (Appendix C.1.).

In Hoktaheen Lake, of the 95 scales aged, the proportion of 2.3 was highest (20%) for males and the 1.3 age class was dominant for female sockeye salmon adults (11.6%; Table 6). The mean fork length for 2.3 males was 565 mm and for 1.3 females was 533 mm (Table 7).

Table 4. Age composition of sockeye salmon adults returning to Kook Lake by sex, brood year, and age, 9 September to 10 October 2001.

Brood Year	1997	1996	1996	
Age	1.2	1.3	2.2	Total
Male				
Sample Size	16	10		26
Percent	42.1	26.3		68.4
Std. Error	7.7	6.9		7.3
Female				
Sample Size	5	4	2	12
Percent	13.2	10.5	5.3	31.6
Std. Error	5.3	4.8	3.5	7.3
All Fish				
Sample Size	21	14	2	38
Percent	55.3	36.8	5.3	100
Std. Error	7.8	7.5	3.5	

Table 5. Mean fork length (mm) of sockeye salmon adults returning to Kook Lake by sex, brood year, and age, 9 September to 10 October 2001.

Brood Year	1997	1996	1996		
Age	1.2	1.3	2.2	No Age	Total
Male	497	555		525	521
Std. Error	11.0	5.2		9.2	6.9
Sample Size	16	10		10	36
Female	496	543	503	518	516
Std. Error	6.3	3.3	12.5	7.3	5.4
Sample Size	5	4	2	7	18
All	497	551	503	522	519
Std. Error	8.4	4.0	12.5	6.1	4.9
Sample Size	21	14	2	17	54

Table 6. Age composition of sockeye salmon adults returning to Hoktaheen Lake by sex, brood year, and age, 3 September to 20 September 2001.

Brood Year	1998	1997	1996	1996	1995	
Age	1.1	1.2	1.3	2.2	2.3	Total
Male						
Sample Size	3	10	17	11	19	60
Percent	3.2	10.5	17.9	11.6	20	63.2
Std. Error	1.7	3	3.7	3.1	3.9	4.6
Female						
Sample Size	1	8	11	6	9	35
Percent	1.1	8.4	11.6	6.3	9.5	36.8
Std. Error	1	2.7	3.1	2.3	2.8	4.6
All Fish						
Sample Size	4	18	28	17	28	95
Percent	4.2	18.9	29.5	17.9	29.5	100
Std. Error	1.9	3.8	4.4	3.7	4.4	

Table 7. Mean fork length (mm) of sockeye salmon adults returning to Hoktaheen Lake by sex, brood year, and age, 3 September to 20 September 2001.

Brood Year	1998	1997	1996	1996	1995		
Age	1.1	1.2	1.3	2.2	2.3	No Age	Total
Male	327	477	562	504	565	517	526
Std. Error	6.0	11.2	10.9	9.6	5.1	37.1	8.4
Sampe Size	3	10	17	11	19	6	66
Female	300	484	533	481	558	460	511
Std. Error		8.6	11.7	9.3	8.7		9.4
Sampe Size	1	8	11	6	9	1	36
All	320	480	551	496	563	509	521
Std. Error		7.1	8.4	7.4	4.4		6.4
Sampe Size	4	18	28	17	28	7	102

Limnology

Limnology sampling was conducted at Gut Bay Lake on 15 May, 29 June, 10 Aug., and 2 Oct. Limnology sampling was conducted at Kook Lake on 17 May, 7 July, 3 Sept., and 17 Oct. At Hoktaheen Lake sampling was conducted on 8 July, 4 Sept., and 20 Oct.

Light

The mean euphotic zone depth was 11 m in Gut Bay Lake, 6 m in Kook Lake, and 3 m in Hoktaheen Lake (Table 8). These three lakes show a gradient in the degree of organic staining: Gut Bay Lake is lightly stained, Kook Lake is moderately dark, and Hoktaheen, which is a muskeg lake, is very dark. Euphotic zone depth in Gut Bay Lake was deeper in mid-summer than in spring or fall. The euphotic zone depth was more constant through the season in Kook and Hoktaheen Lakes, deepening only slightly in mid-summer.

Table 8. Lake euphotic zone depths in 2001.

Lake	Date	EZD (m)
Gut Bay	15-May	9.83
	29-Jun	14.07
	10-Aug	12.53
	2-Oct	7.22
	seasonal mean	10.91
Kook	16-May	5.67
	7-Jul	6.99
	3-Sep	5.54
	17-Oct	5.08
	seasonal mean	5.82
Hoktaheen	8-Jul	3.41
	20-Sep	3.16
	2-Oct	2.91
	seasonal mean	3.16

Temperature and Dissolved Oxygen

Water temperature vertical profiles for the three lakes show the seasonal thermal stratification pattern typical of dimictic lakes (Figure 7). The pattern appears weak for Gut Bay Lake, but no late summer temperature profile was taken. The temperature exceeded the lethal limit of sockeye salmon, 10^{o} C, above about 4 m on 29 June only. The thermocline formed at about 14 m in Kook Lake and deepened slightly over the summer. The temperature exceeded 10^{o} C above about 10 m on 7 July and about 14 m on 3 September in Kook Lake. In Hoktaheen Lake, the thermocline formed at 3–5 m and deepened to about 7 m. The temperature exceeded 10^{o} C above about 5 m on 8 July and above 8 m on 4 September. Maximum epilimnetic temperatures were about 13^{o} C in all three lakes, and hypolimnetic temperatures were about 5^{o} C. Dissolved oxygen (DO) profiles remained uniformly above 10 mg $\cdot$ L^{-1} in all lakes at most dates and depths (Appendix C). Dissolved oxygen dipped slightly below 10 mg $\cdot$ L^{-1} at the lowest depths in Gut Bay and Kook Lakes in October; the minimum DO of 4.7 mg $\cdot$ L^{-1} at 45 m in Kook Lake may have resulted from a reading within the sediment layer.

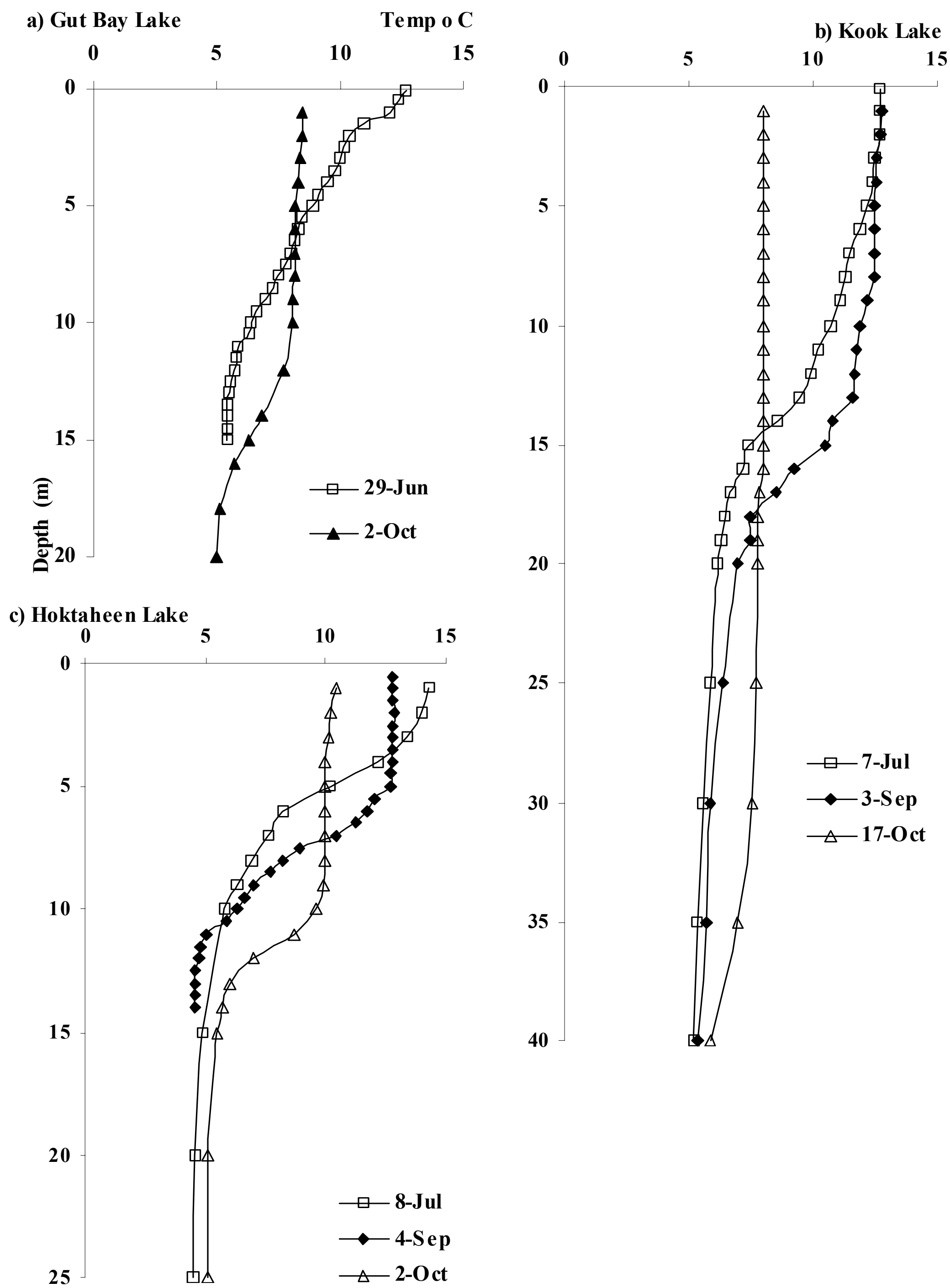

Figure 7. Seasonal water temperature profiles for: a) Gut Bay, b) Kook, and c) Hoktaheen Lakes in 2001.

Secondary Production

Gut Bay Lake had very low zooplankton density in 2001 compared with other sockeye nursery lakes in Alaska (Kyle 1996; Table 9). *Bosmina* sp. dominated the species composition, and accounted for 75% of the zooplankton population numerically and 88% of the biomass. However, individuals were small; the seasonal mean weighted length of sampled *Bosmina* sp. was 0.34 mm (Appendix C.5). *Copepod* nauplii were the second largest contributors overall to density and persisted or increased through the season; mature *Cyclops* as well as *Daphnia longiremus* and *Holopedium* were present at low densities. Zooplankton density increased dramatically during the season, especially that of the cladocerans *Bosmina* and *Daphnia* (Appendix C.4). One scheduled zooplankton sampling date in Gut Bay Lake was missed in late summer due to weather and hazardous flying conditions.

Zooplankton density in Kook Lake was low (Kyle 1996; Table 10). In Kook Lake, there was a mix of three to four dominant species, including *Cyclops* sp., *Bosmina* sp., *Daphnia longiremus*, and *Holopedium* sp., with *Bosmina* present in greatest numbers overall and *Holopedium* having the greatest overall biomass. The peak abundance of the larger cladoceran, *D. longiremus,* was in early summer. The seasonal mean weighted length of sampled *D. longiremus* was 0.87 mm, and the mean weighted length for ovigerous individuals was 1.06 mm (Appendix C.6 and C.7). Peak abundance of the smaller *Bosmina* sp. was in early fall. Individual *Bosmina* sp. had a seasonal mean weighted length of 0.52 mm and 0.62 mm for ovigerous individuals, somewhat larger than *Bosmina* sp. sampled at Gut Bay Lake. Kook Lake was sampled for zooplankton at all four scheduled dates.

Zooplankton density and biomass were higher in Hoktaheen Lake, but were dominated by the small copepod *Cyclops* sp. which comprised 69–77% of numerical abundance overall and 65–72% of biomass (Kyle 1996; Table 11). *Bosmina* sp. comprised most of the remaining zooplankton population, with 17–24% of numerical abundance and 19–23% of biomass overall. Two species of *Daphnia* were present, *D. longiremus* and the larger *D. middendorffiana*, and comprised from 9–12% of the biomass. A high proportion of *D. longiremus* were ovigerous. Other than copepod nauplii of unidentified taxa, no other genera of zooplankton were observed in Hoktaheen Lake. *Cyclops* abundance declined markedly over the season, while the abundance of *Bosmina* peaked in late summer and then declined, and the pattern for *Daphnia* varied between species and sites (Appendix C.8). *Bosmina* was the smallest species, with seasonal mean weighted length of 0.47 mm; *Cyclops* seasonal mean weighted length was 0.72 mm (Appendix C.9). The seasonal mean weighted length of *Daphnia longiremus* was 0.87 mm, while *D. middendorffiana* were nearly twice as large, at 1.65 mm. The first scheduled zooplankton sampling date in Hoktaheen Lake, in May, was missed due to hazardous flying conditions.

Table 9. Species distributions of macro-zooplankton in Gut Lake, 2001. Zooplankton densities (number · m^{-2}) and mean weighted biomass (mg · m^{-2}) are seasonal mean values from four samples, collected at six week intervals May through October, at two permanent sampling stations. Overigerous (egg-bearing) individuals in each taxon were enumerated separately.

Station A	**Density (no. · m^{-2})**	**Percent of Total Numbers**	**Biomass (mg · m^{-2})**	**Percent of Total Biomass**
Ergasilus				
Epischura				
Diaptomus				
Ovig. Diaptomus				
Cyclops	1,622	4%	1	3%
Bosmina	27,492	66%	28	74%
Ovig. Bosmina	6,320	15%	6	16%
Daphnia l.	637	2%	1	3%
Ovig. Daphnia l.	28	0%	0.06	0%
Daphnia g.	0	0%		0%
Holopedium	450	1%	1	3%
Ovig. Holopedium	210	1%	1	3%
Chydorinae	113	0%	0.08	0%
Sida crystalina	0	0%	0	0%
Copepod nauplii	5,072	12%		0%
Total	41,944		38	
Station B				
Ergasilus				
Epischura				
Diaptomus				
Ovig. Diaptomus				
Cyclops			3	11%
Ovig. Cyclops	3,478	10%		
Bosmina	20,765	58%	19	68%
Ovig. Bosmina	4,392	12%	5	18%
Daphnia l.	280	1%	0.45	2%
Ovig. Daphnia l.	34	0%	0.09	0%
Daphnia g.	0	0%		0%
Holopedium	337	1%	0.49	2%
Ovig. Holopedium	68	0%	0.18	1%
Chydorinae	167	0%	0.12	0%
Sida crystalina	0	0%		0%
Copepod nauplii	6,153	17%		0%
Total	35,674		28	

Table 10. Species distributions of macro-zooplankton in Kook Lake, 2001. Zooplankton densities (number · m^{-2}) and mean weighted biomass (mg · m^{-2}) are seasonal mean values from four samples, collected at six week intervals May through October, at two permanent sampling stations. Overigerous (egg-bearing) individuals in each taxon were enumerated separately.

Station A	**Density (no. · m^{-2})**	**Percent of Total Numbers**	**Biomass (mg · m^{-2})**	**Percent of Total Biomass**
Ergasilus	0	0%		0%
Epischura	0	0%		0%
Diaptomus	883	1%	7	2%
Ovig. Diaptomus	85	0%	1	0%
Cyclops	22,873	29%	59	18%
Ovig. Cyclops	1,078	1%	6	2%
Bosmina	27,017	34%	61	19%
Ovig. Bosmina	1,002	1%	3	1%
Daphnia l.	10,723	14%	37	12%
Ovig. Daphnia l.	552	1%	3	1%
Holopedium	3,974	5%	36	11%
Ovig. Holopedium	10,155	13%	109	34%
Chydorinae	17	0%	0	0%
Sida crystalina		0%		0%
Copepod nauplii	1,129	1%		0%
Total	79,487		323	
Station B				
Ergasilus	0	0%		0%
Epischura	0	0%		0%
Diaptomus	2,938	4%	16	6%
Ovig. Diaptomus	68	0%	1	0%
Cyclops	18,687	24%	52	19%
Ovig. Cyclops	1,274	2%	7	3%
Bosmina	34,374	45%	98	36%
Ovig. Bosmina	1,108	1%	4	2%
Daphnia l.	9,667	13%	32	12%
Ovig. Daphnia l.	319	0%	2	1%
Holopedium	7,068	9%	56	21%
Ovig. Holopedium	416	1%	7	3%
Chydorinae	0	0%		0%
Sida crystalina		0%		0%
Copepod nauplii	662	1%		0%
Total	76,580		275	

Table 11. Species distributions of macro-zooplankton in Hoktaheen Lake, 2001. Zooplankton densities (number · m^{-2}) and mean weighted biomass (mg · m^{-2}) are seasonal mean values from four samples, collected at six week intervals May through October, at two permanent sampling stations. Overigerous (egg-bearing) individuals in each taxon were enumerated separately.

Station A	**Density (no. · m^{-2})**	**Percent of Total Numbers**	**Biomass (mg · m^{-2})**	**Percent of Total Biomass**
Ergasilus	0	0%		
Epischura	0	0%		
Diaptomus	0	0%		
Cyclops	86,036	68%	167	62%
Ovig. Cyclops	1,698	1%	8	3%
Bosmina	28,698	23%	59	22%
Ovig. Bosmina	1,132	1%	3	1%
Daphnia l.	2,264	2%	8	3%
Ovig. Daphnia l.	1,755	1%	9	3%
Daphnia m.	906	1%	12	5%
Ovig. Daphnia m.	57	0%	1	1%
Holopedium	0	0%		
Chydorinae	0	0%		
Polyphemus	0	0%		
Copepod nauplii	4,302	3%		
Total	126,846		268	
Station B				
Ergasilus	0	0%		
Epischura	0	0%		
Diaptomus	0	0%		
Cyclops	155,997	76%	252	69%
Ovig. Cyclops	2,547	1%	12	3%
Bosmina	31,980	16%	62	17%
Ovig. Bosmina	1,754	1%	6	2%
Daphnia l.	4,528	2%	14	4%
Ovig. Daphnia l.	623	0%	3	1%
Daphnia m.	1,245	1%	16	4%
Ovig. Daphnia m.	0	0%	0	0%
Holopedium	0	0%		
Chydorinae	0	0%		
Polyphemus	0	0%		
Copepod nauplii	5,604	3%		
Total	204,279		365	

DISCUSSION

In the first year of the Gut Bay, Kook, and Hoktaheen lake sockeye salmon projects, we completed the objectives to estimate the sockeye fry population, and describe the size and age structure of fry and adult sockeye populations and the productivity of these three lakes. However, we had a difficult time estimating the sockeye salmon adult returns in Gut Bay, Kook, and Hoktaheen lakes for a variety of reasons. The number of fish present was low in Gut Bay and Kook lakes and low to moderate in Hoktaheen. Small sample sizes, resulting from small escapements, affected the precision of the mark-recapture estimates. There were also problems at all three lakes in choosing an appropriate index area from which an escapement estimate could be extrapolated to the whole lake. In Gut Bay Lake, the fish were dispersed thinly around the lake so it was difficult to select one area with sufficient numbers of fish to represent the spawning population. Furthermore, large woody debris and dense overhanging alders blocked access to most of the spawning areas for beach seining. However, the evenly dispersed fish allowed us to estimate the number of spawners visible along the shore with a fair amount of confidence. An additional complication was that observer counts of spawners in the shore areas increased late in the season and still had not peaked by the end of October. In Kook Lake, only beach spawning areas were sampled, and the density of spawners varied considerably between areas over the season. ADF&G has observed sockeye salmon spawning in the inlet stream in the past but no fish were present in the inlet in 2001. Because early returning sockeye salmon spawn in the inlet and later returning fish spawn in beach areas, the presence of a debris barrier until mid-August may explain why we did not see fish in the inlet stream this year (A. McGregor, ADF&G, personal communication, 2001). In Hoktaheen, only the inlet stream spawning population was estimated, but there was a small group of beach spawners and outlet stream spawners as well. The small lake and the outlet stream below the small lake were not surveyed or sampled. Therefore, the number of spawners in these areas is unknown. Also unknown is whether fry hatched in the outlet stream migrate upstream into the main lake or downstream into the smaller lake, or both. If the downstream lake provides additional fry habitat, the fry density and total fry population estimates from the larger lake represent a minimum number of fry present. A similar situation exists at Klag Lake on the west coast of Chichagof Island, which has many physical similarities to Hoktaheen Lake (Conitz and Cartwright 2002a). If time allows, the hydroacoustic survey will include the smaller lake, however, it may be too shallow to sample with a mid-water trawl. Next year, an additional mark-recapture study site will be added in the outlet stream. We were only able to complete two sampling events at Hoktaheen Lake due to weather and hazardous flying conditions.

In these mark-recapture studies, the estimate of sockeye salmon within a selected index area represents an unknown part of the total escapement. In extrapolating index area populations to an entire lake system, we are making an untested assumption that the spawning sockeye salmon population within the index area is representative of the population of the whole lake (Crabtree 2000 and 2001). We most likely are not able to observe all the spawners, therefore, the whole lake estimates must be viewed as the minimum number of fish spawning with an unknown proportion of the population unaccounted for in this estimate.

Nevertheless, these rough estimates of adult sockeye salmon escapements in Gut Bay and Kook lakes appear to confirm community concerns about low numbers returning to these systems. The escapement at Hoktaheen Lake also appeared to be low to moderate; however, there are no records of historic runs in this system. Continued monitoring of these systems will allow us to see if these low escapement numbers prevail throughout the five-year cycle of sockeye salmon stocks or if they were only unusually low this year.

Because we only have sockeye salmon fry population estimates from one year, it is too soon to use these estimates as reliable indicators of productivity, but there are some preliminary comparisons that can be made. Out of 13 sockeye rearing lakes in Southeast Alaska examined in 2001, Gut Bay Lake, with the smallest surface area, ranked third highest in fry density (Table 12). This fry population estimate contrasts with the very low escapement estimates this year and in past aerial surveys (Appendix B.1). Gut Bay Lake has a relatively deep euphotic zone compared to other sockeye rearing lakes in Southeast Alaska, which creates a large photogenic zone and could potentially support high primary and secondary production (Table 13). A high zooplankton population can potentially support a larger sockeye salmon fry population, however, the size of cladocerans was small, indicating that the grazing pressure on these species may already be high.

Kook Lake had the lowest in fry density of 18 lakes in Southeast, suggesting that the adult return was low last year. A debris barrier in the outlet stream may have prevented adults from returning for at least the past several years. Previous estimates of juvenile populations in Kook Lake in the mid-1990s are close to the estimate in 2001 (Table 1). One possible explanation is that the debris barrier has prevented fish returning for many years. Kook Lake has moderate secondary production, with relatively large numbers of larger cladocerans, especially *Daphnia*, which could potentially support greater numbers of sockeye salmon fry. Hoktaheen Lake had a relatively high density of fry, ranking fourth among the lakes studied, and it had the second shallowest euphotic zone depth (Tables 12 and 13). Zooplankton data from 2001 suggest this lake produces good numbers of the larger zooplankton, including many reproductive individuals, who may promote sockeye salmon fry production. Of the three lakes in this study, Hoktaheen had the warmest epilimnetic temperatures, which may have a positive effect on secondary production. Its shallow euphotic zone depth indicates highly stained water, which can absorb and retain more heat during the growing season (Edmundson and Mazumder 2001).

Table 12. Fry density estimates ($fry \cdot m^{-2}$) from hydroacoustic surveys conducted in 2001 for 18 sockeye salmon lakes important to subsistence users in Southeast Alaska.

Lake	**Density ($fry \cdot m^{-2}$)**
Kanalku	<0.01
Mahoney	<0.01
Redoubt	0.01
Chilkat	0.01
Kook	0.03
Klawock	0.07
Salmon Bay	0.07
Chilkoot	0.09
Falls	0.09
Luck	0.10
Sitkoh	0.14
Klag	0.14
Salmon	0.14
Kutlaku	0.23
Hoktaheen	0.25
Gut	0.32
Thoms	0.89
Hetta	1.20

Table 13. The summary of the seasonal mean euphotic zone depth (EZD) for 12 sockeye salmon lakes important to subsistence users.

Lake	EZD (m)
Thoms	3.00
Hoktaheen	3.16
Klawock	4.24
Klag	4.56
Salmon Bay	4.60
Luck	4.60
Kook	5.82
Sitkoh	6.69
Hetta	7.94
Falls	9.71
Gut Bay	10.91
Kanalku	11.06

Sockeye salmon fry population estimates are important in studying the spawner-recruit relationship and in estimating ocean survival. Fry survival and growth in the lake system are indicators of rearing habitat carrying capacity and adult returns from a known smolt population provide an estimate of marine survival. Information about both of these environmental relationships is important to good management of sockeye salmon stocks. The mid-water trawl and hydroacoustic sampling methods are being evaluated and may be redesigned to represent a true replicate survey and to minimize sampling errors.

The age distribution of adult sockeye salmon returning to Kook and Hoktaheen lakes in 2001 must be viewed with caution because the sample sizes were small. In addition, the annual age class proportions are controlled by brood year strength and the 2001 results are based on only a single return year. Kook Lake was the only lake in this project that had previous biological data to compare with data collected in 2001. The 1.3 age class dominated the age distribution in most years in the past. Similar to the 2001 sockeye salmon adult age structure, two out the six years of historical biological samples showed a higher proportion of the 1.2 age class returning to Kook Lake (Appendix B.4). Typically, a strong 1.2 age class will follow a year when the 1.3 age class is strong (A. McGregor personal communication).

In each of these systems, multi-year series of reliable escapement estimates are the minimum information needed to assess the health of these sockeye salmon populations and set sustainable harvest levels and escapement goals. Additional information from fry population estimates, size and age distribution of adult sockeye salmon, and lake ecology data should improve the quality of the adult population estimates, and may identify trophic level interactions and possible bottlenecks that can help us understand the dynamics of the sockeye populations in each system. Data from the first year of this project provide a starting point, but study of these systems should continue for at least four to five more years to capture the environmental and biological annual variation. In the upcoming field season, we specifically need to improve upon the following: 1) describe all the spawning areas used by sockeye salmon in each system, including inlet and outlet streams, 2) obtain accurate observer counts in all these areas in each system by every crew member present, on a regular schedule through the spawning season, and 3) compare observer counts with mark-recapture estimates in one or more “index areas” that are used by a high proportion of the spawners in that system.

Regrouping the lakes into other projects is necessary to improve logistics and safety and reduce costs; these changes will enable us to focus on improving the quality of data. Although Gut Bay Lake will remain in this cooperative project with OVK, we may limit data collection to a lake survey while the plane stands by. If a large number of sockeye adults return and concentrate in an area appropriate for beach seining, we will attempt to do a mark-recapture study. Kook Lake will be added to the cooperative project with the Angoon Community Association (Conitz and Cartwright 2002b). Kook Lake has been a traditional sockeye salmon fishing area for the Angoon people in the past, and the Angoon community is interested in continuing to be stewards of this sockeye salmon run. Hoktaheen Lake is an important traditional sockeye salmon fishing area for the people of Hoonah, and the Hoonah Indian Association is starting a new cooperative sockeye stock assessment project in 2002 to include Hoktaheen. The Kake project will add Kutlaku and Falls Lake for the spawning ground mark-recapture study.

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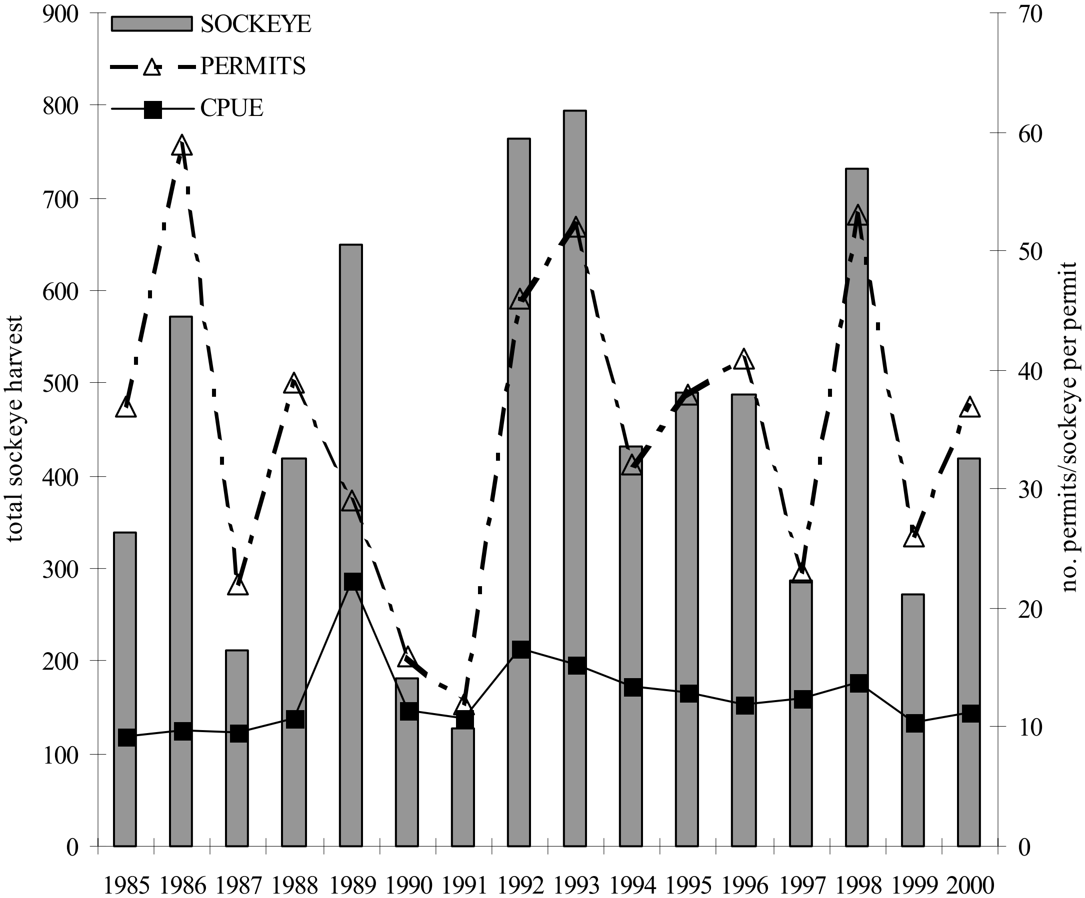
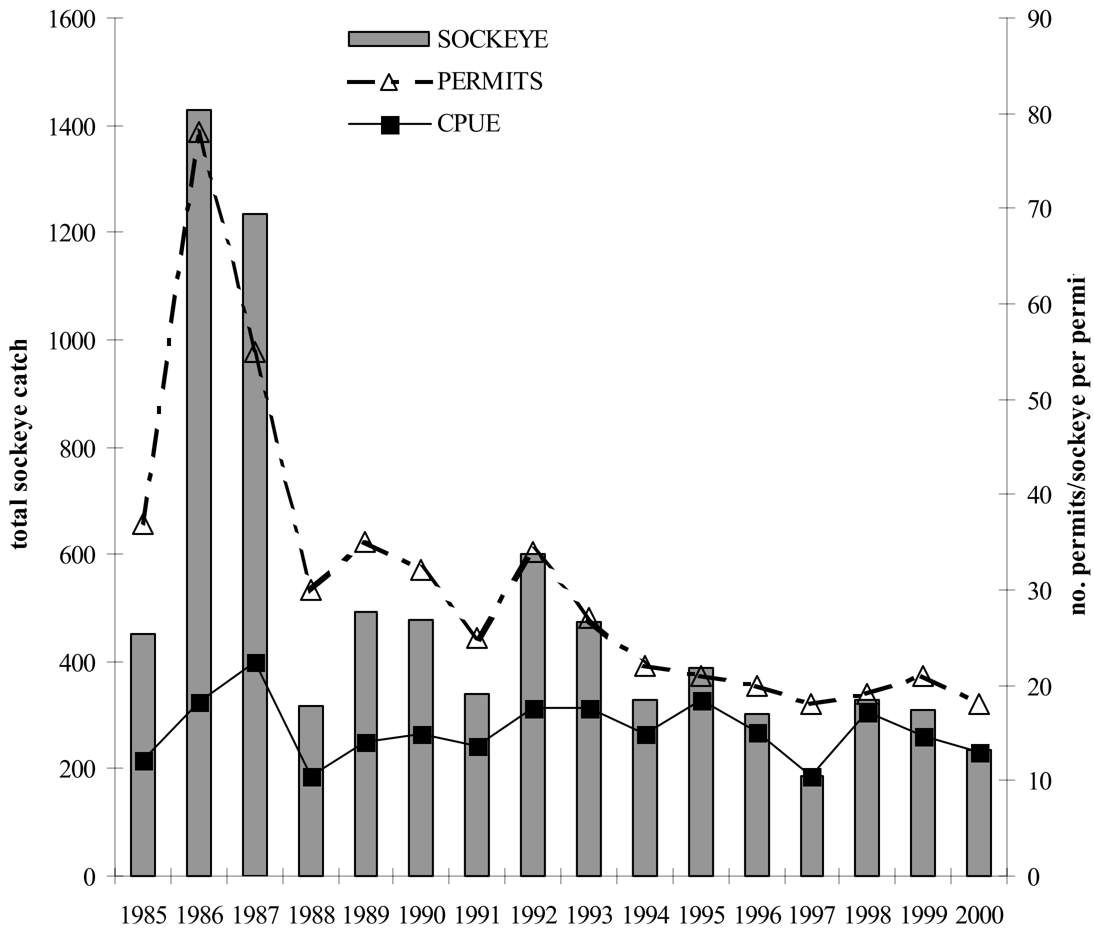
APPENDICES

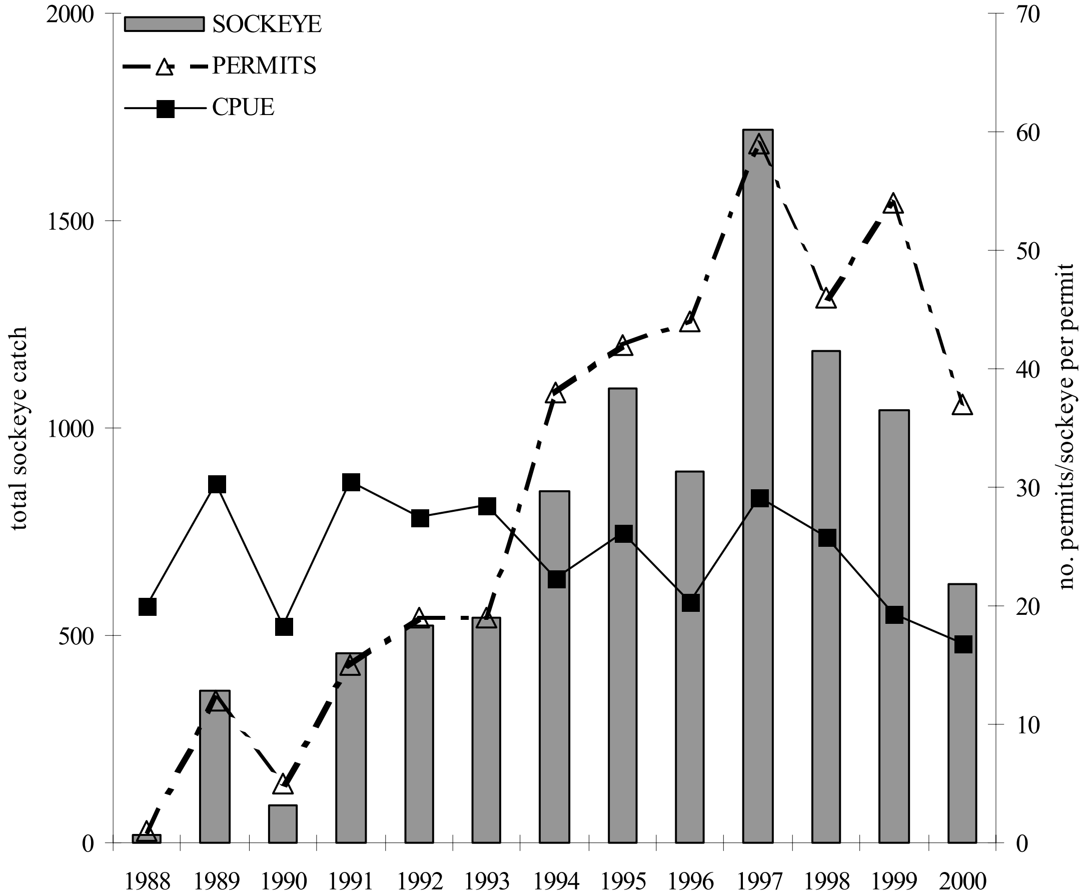
Appendix A. Historical sockeye salmon harvest information from Gut Bay, Kook, and Hoktaheen lakes.



Appendix A.1. Subsistence harvest of sockeye salmon reported on permits from Gut Bay, 1985–2000 (ADF&G Alexander Database, 2002).



Appendix A.2. Subsistence harvest of sockeye salmon reported on permits from Basket Bay (Kook Lake), 1985–2000. (ADF&G Alexander Database, 2002).



Appendix A.3. Subsistence harvest of sockeye salmon reported on permits from Hoktaheen Creek, 1988–2000 (ADF&G Alexander database, 2002).

Appendix A.4. Sport fishing data from Kook Lake and Hoktaheen Cove. The Division of Sport Fish did not record the number of fish caught and released before 1990 (ADF&G database).

Lake/ Area	**Year**	**Number of Anglers**	**Number of Trips**	**Sockeye Caught**	**Sockeye Kept**
Kook lake	1984	72	92	0	0
	1985	33	31	0	0
	1988	85	28	0	910
	1989	53	35	0	68
	1990	34	17	0	0
	1991	88	53	994	33
	1992	37	37	0	0
	1993	44	108	0	0
	1994	40	105	0	0
	1999	30	26	0	0
Hoktaheen saltwater and freshwater	1988	57	57		0
	1992	75	212	0	0
	1993	13	14	0	0
	1994	39	39	494	228
	1999	48	38	432	345

Appendix A.5. Historic commercial fishery data for Gut Bay, Basket Bay, and Hoktaheen Cove (Rich and Ball, 1933).

		Total Sockeye Harvest	
Year	**Gut Bay**	**Basket Bay**	**Hoktaheen Cove**
1892	1,673		
1893	2,766		
1894	630		
1895	6,716		
1896	2,326	21,175	
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1900		61,500	
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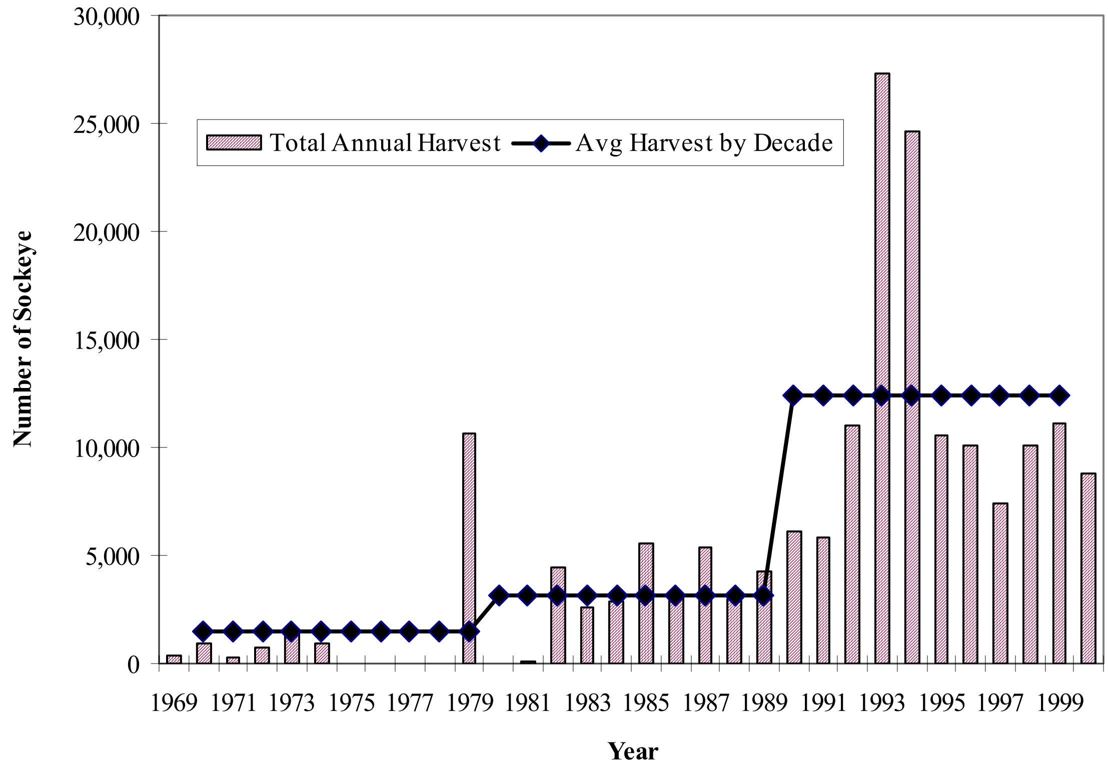
1904	20,000	86,000	
1905	7,000	-	8,279
1906	2,500	-	11,348
1907	-	-	7,000
1908	1,302	-	10,677
1909	2,703	-	10,391
1910	4,905	-	9,896
1911	4,371	-	7,196
1912	100	2,968	7,197
1913	1,723	-	5,344
1914	1,777	-	7,686
1915	3,234	-	8,301
1916	12,009	-	-
1917	1,057	-	-
1918	1,500	314	2,519
1919	22,572	-	5,463
1920	10,402	892	3,218
1921	7,120	-	-
1922	4,514	523	653
1923	215	910	5,266
1924	10,551	221	2,310
1925		-	2,335
1926		962	1,834
1927		2,340	2,021



Appendix A.6. Commercial sockeye harvest in vicinity of Falls Lake and Gut Bay, all gear types (Larson 2001).

Appendix B. Historical sockeye salmon escapement data from Gut Bay, Kook, and Hoktaheen Lakes.

Appendix B.1. Escapement survey counts of sockeye salmon in Gut Bay (ADF&G Alexander Database, 2002).

Year	**Peak Sockeye Count**	**Number of Surveys**	**Type of Survey**
1963	2,500	1	FOOT
1966	500	1	AERIAL
1968	100	1	AERIAL
1969	800	2	HELICOPTER
1970	1,000	1	AERIAL
1974	200	1	AERIAL
1977	1,500	1	AERIAL
1980	100	1	AERIAL
1983	200	1	AERIAL
1985	400	1	AERIAL
1996	3	1	AERIAL
1997	120	2	AERIAL
1998	50	2	AERIAL
2000	100	3	AERIAL

Appendix B.2. Escapement survey counts of sockeye salmon in Kook Lake, 1972–2000 (ADF&G Alexander Database, 2002).

Location	Year	Date of Peak Count	Sockeye Peak Count	Number of Surveys	Survey Type
Kook Creek (Inlet)	1972	08/02	300	3	AERIAL
	1981	09/25	250	2	AERIAL
	1982	08/17	730	2	AERIAL
	1983	08/10	1,820	4	FOOT
	1984	09/27	2,500	3	AERIAL
	1985	07/29	100	2	AERIAL
	1986	08/07	550	4	AERIAL
	1987	08/02	400	3	AERIAL
	1988	08/16	300	2	AERIAL
	1989	08/06	450	6	AERIAL
	1989	08/10	450	6	AERIAL
	1990	07/25	150	4	AERIAL
	1991	07/29	200	3	AERIAL
	1992	08/11	1,192	3	FOOT
	1999	08/11	25	1	AERIAL
	2000	08/02	100	2	AERIAL
Kook Lake	1981	09/01	130	1	AERIAL
	1986	09/16	250	4	AERIAL
	1987	09/15	230	2	AERIAL
	1988	09/26	50	2	AERIAL
	1989	09/14	100	2	AERIAL
	1990	09/12	100	1	AERIAL
	1991	09/11	200	1	AERIAL
	1992	07/30	200	1	AERIAL
	1995	09/05	10	1	AERIAL
	1998	09/16	30	1	AERIAL

Appendix B.3. Escapement survey counts of sockeye salmon in Hoktaheen Cove and Creek (ADF&G Alexander Database, 2002).

Year	Date	Number of Sockeye	Number of Surveys	Survey Type
1965	08/01	3,000	1	AERIAL
1968	06/24	1,000	2	FOOT
1969	07/03	1,500	1	AERIAL
1973	07/05	500	1	AERIAL
1977	06/15	1,500	1	AERIAL
1978	06/28	500	1	BOAT
-	-	-	-	-
1997	07/21	2	1	AERIAL
1999	07/28	150	1	AERIAL
2000	09/15	354	2	AERIAL

Appendix B.4. Historical age and length composition of Kook Lake sockeye salmon escapement.

	Percent in Age Class by Return Year							
Age class	**1983**	**1984**	**1985**	**1987**	**1994**	**1995**	**Average**	**SE**
0.2	0	0	0	0	0	0.1	0.1	0
0.3	0	0	0	0	0.1	0	0	0
1.1	0	0	0	0	0.2	0	0.1	0
1.2	5	4.3	50	0	71.8	39	34.1	0.8
1.3	94.8	95.7	29.6	99.2	21.7	53.3	61	0.8
1.4	0	0	13	0.3	0	0	0.2	0.1
2.1	0	0	0	0	0.1	0	0	0
2.2	0	0	0	0	4.9	3.3	2.5	0.3
2.3	0.2	0	7.4	0.5	0.8	4.3	2	0.2
3.2	0	0	0	0	0.2	0	0.1	0

	Average length by Return Year							
Age class	**1983**	**1984**	**1985**	**1987**	**1994**	**1995**	**Average**	**SE**
0.2	0	0	0	0	0	515	515	5
0.3	0	0	0	0	545	0	545	0
1.1	0	0	0	0	372	0	372	12.5
1.2	473	498	466	0	467	488	477	0.7
1.3	559	560	540	576	535	535	552	0.6
1.4	0	0	570	605	0	0	574	9.1
2.1	0	0	0	0	340	0	340	0
2.2	0	0	0	0	484	498	491	2.3
2.3	570	0	531	570	532	538	539	3.4
3.2	0	0	0	0	480	0	480	10
Average	555	557	506	576	483	516	524	
SE	26.5	25.7	6.8	31.6	16.7	14	8.9	

Appendix C. Adult sockeye salmon age and length data from sampling in 2001.

Appendix C.1. Age and length data of adult sockeye spawners in Kook Lake, 2001

Date	Sample No	Sex	Length	Age	Readability
9/9/2001	1	1	560		regenerated scale
9/9/2001	2	2	490	2.2	
9/9/2001	3	1	530		regenerated scale
9/9/2001	4	2	500	1.2	
9/9/2001	5	1	485	1.2	
9/9/2001	6	1	545	1.3	
9/9/2001	7	2	490		regenerated scale
9/9/2001	8	1	535	1.3	
9/9/2001	9	2	535	1.3	
9/9/2001	10	1	480	1.2	
9/9/2001	11	2	535		regenerated scale
9/9/2001	12	1	545	1.3	
9/9/2001	13	1	530		regenerated scale
9/9/2001	14	1	590	1.3	
9/9/2001	15	1	565	1.3	
9/9/2001	16	2	540		regenerated scale
9/9/2001	17	1	565	1.3	
9/9/2001	18	2	515	2.2	
9/9/2001	19	2	550	1.3	
9/9/2001	20	1	490	1.2	
9/9/2001	21	2	510	1.2	
9/9/2001	22	1	505	1.2	
9/26/2001	1	2	540	1.3	
9/26/2001	2	1	530	1.2	
9/26/2001	3	2	474	1.2	
9/26/2001	4	1	485	1.2	
9/26/2001	5	1	496	1.2	
9/26/2001	6	1	539	1.2	
9/26/2001	7	1	547	1.3	
9/26/2001	8	1	549	1.3	
9/26/2001	9	1	566	1.3	
9/26/2001	10	1	533	1.2	
9/26/2001	11	1	542	1.3	
9/26/2001	12	2	511		regenerated scale
9/26/2001	13	1	358	1.2	
9/26/2001	14	1	462	1.2	
9/26/2001	15	1	530		regenerated scale
9/26/2001	16	1	533		regenerated scale
9/26/2001	21	1	530	1.2	
9/26/2001	22	1	533	1.2	
9/26/2001	23	1	572		regenerated scale
9/26/2001	24	1	498		regenerated scale
9/26/2001	25	1	528		regenerated scale
9/26/2001	26	2	546	1.3	
9/26/2001	27	2	491	1.2	
9/26/2001	28	1	522	1.2	
9/26/2001	29	2	522		regenerated scale
9/26/2001	30	1	516	1.2	
10/10/2001	1	1	488		regenerated scale
10/10/2001	2	2	498		regenerated scale
10/10/2001	3	1	481		regenerated scale
10/10/2001	4	1	492	1.2	
10/10/2001	5	2	505	1.2	
10/10/2001	6	2	533		regenerated scale

Appendix C.2. Age and length data of adult sockeye salmon spawners returning to Hoktaheen Lake, 2001.

Date	Sample No	Sex	Length	Age	Readability
9/29/01	10	1	540	1.3	
9/28/01	9	2	490	1.3	
9/27/01	8	1	540		regenerated scale
9/26/01	7	2	450	1.2	
9/26/01	7	1	450	1.2	
9/25/01	6	2	460		regenerated scale
9/25/01	6	1	640	1.3	
9/24/01	5	1	570	1.3	
9/24/01	5	1	600	2.3	
9/23/01	4	2	530	1.3	
9/23/01	4	2	580	2.3	
9/22/01	3	1	545		regenerated scale
9/22/01	3	2	445	2.2	
9/21/01	2	2	470	2.2	
9/21/01	2	2	560	2.3	
9/20/01	1	1	510	1.2	
9/20/01	1	2	445	1.3	
9/4/01	1	1	550	1.3	
9/4/01	40	1	335		regenerated scale
9/4/01		1	530		regenerated scale
9/4/01		1	570		regenerated scale
9/4/01		1	440	1.2	
9/4/01		2	600	2.3	
9/4/01		1	550	2.3	
9/4/01		1	590	1.3	
9/4/01		1	570	1.3	
9/4/01		2	300	1.1	
9/4/01		2	520	1.2	
9/4/01		1	530	2.2	
9/4/01		2	540	1.3	
9/4/01		1	570	1.3	
9/4/01		1	545	1.3	
9/4/01		2	570	1.3	
9/4/01		1	330	1.1	
9/4/01		1	315	1.1	
9/4/01		2	490	1.2	
9/4/01		1	580	1.3	
9/4/01		2	550	1.3	
9/4/01		2	520	1.3	
9/4/01		1	560	2.3	
9/4/01		1	560	2.3	
9/4/01		1	570	2.3	
9/4/01		1	580	2.3	
9/4/01		2	580	1.3	
9/4/01		1	530	2.3	
9/4/01		1	510	2.2	
9/4/01		1	490	1.2	
9/4/01		1	470	1.2	
9/4/01		1	535	2.3	
9/4/01		1	530	1.3	
9/4/01		1	520	2.2	
9/4/01		2	580	2.3	
9/4/01		1	430	1.2	
9/4/01		1	575	2.3	
9/4/01		2	530	1.3	
9/4/01		2	480	2.2	

-continued-

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Date	Sample No		Sex	Length	Age	Readability
9/4/01		2	485	1.2		
9/3/01	1	1	500	1.2		
9/3/01	1	1	495	2.2		
9/3/01	2	1	570	2.3		
9/3/01	2	1	500	2.2		
9/3/01	3	1	570	1.3		
9/3/01	3	2	550	2.3		
9/3/01	4	2	480	2.2		
9/3/01	4	2	550	2.3		
9/3/01	5	1	580		regenerated scale	
9/3/01	5	1	570	2.3		
9/3/01	6	2	560	2.3		
9/3/01	7	2	570	1.3		
9/3/01	8	1	580	1.3		
9/3/01	9	1	530	2.2		
9/3/01	10	1	590	2.3		
9/3/01	11	1	420	1.3		
9/3/01	12	1	550	1.3		
9/3/01	13	1	580	1.3		
9/3/01	14	1	335	1.1		
9/3/01	15	1	570	2.3		
9/3/01	16	1	520	2.2		
9/3/01	17	1	580	2.3		
9/3/01	18	2	450	1.2		
9/3/01	19	1	590	2.3		
9/3/01	20	1	550	2.3		
9/3/01	21	2	480	1.2		
9/3/01	22	1	580	2.3		
9/3/01	23	1	440	1.2		
9/3/01	24	1	605	1.3		
9/3/01	25	1	520	2.2		
9/3/01	26	1	520	2.2		
9/3/01	27	2	530	2.3		
9/3/01	28	1	570	1.3		
9/3/01	29	1	480	2.2		
9/3/01	30	2	500	2.2		
9/3/01	31	1	420	2.2		
9/3/01	32	2	500	1.2		
9/3/01	33	1	570	2.3		
9/3/01	34	2	510	2.2		
9/3/01	35	1	520	1.2		
9/3/01	36	2	500	1.2		
9/3/01	37	2	540	1.3		
9/3/01	38	2	515	2.3		
9/3/01	39	1	510	2.3		
9/3/01	40	1	520	1.2		

Appendix D. Limnology and lake ecology data from 2001.

Appendix D.1. Vertical temperature and dissolved oxygen (DO) profiles for Gut Bay Lake on 29 June, and 2 October 2001. Dissolved oxygen levels are shown as percent saturation at the indicated temperature. The first measurement at 0.1 m was taken just below the lake surface. Measurements below 15 m were taken at 5 m intervals.

	29 Jun.		2 Oct.	
Depth (m)	**Temp (^oC)**	**DO (%)**	**Temp (^oC)**	**DO (%)**
0.1	12.7	104.8	-	-
1.0	12.4	104.5	8.5	96.7
2.0	11.2	104.7	8.5	97.6
3.0	10.7	105.3	8.4	99.3
4.0	9.5	104.8	8.3	107.7
5.0	8.6	104.8	8.2	103.5
6.0	8.1	106.0	8.2	105.0
7.0	7.8	106.1	8.2	105.5
8.0	7.1	105.7	8.2	105.1
9.0	6.6	104.3	8.1	105.6
10.0	6.2	102.3	8.1	104.4
11.0	5.8	99.8	-	-
12.0	5.6	97.4	7.7	96.5
13.0	5.4	94.9	-	-
14.0	5.3	93.0	6.8	93.5
15.0	5.3	91.9	6.3	92.4
20.0	-	-	5.0	75.7

Appendix D.2. Vertical temperature and dissolved oxygen (DO) profiles in Kook Lake on 7 July, 3 September, and 17 October 2001. Dissolved oxygen levels are shown as percent saturation at the indicated temperature. The first measurement at 0.1 m was taken just below the lake surface. Measurements below 20 m were taken at 5 m intervals.

	7 July		3 Sept.		17 Oct.	
Depth (m)	**Temp (^oC)**	**DO (%)**	**Temp (^oC)**	**DO (%)**	**Temp (^oC)**	**DO (%)**
0.1	12.7	120.5				
1.0	12.7	102.4	12.8	98.7	8.0	85.7
2.0	12.7	102.1	12.7	99.9	8.0	85.6
3.0	12.5	101.8	12.6	103.9	8.0	85.5
4.0	12.4	101.6	12.6	112.4	8.0	85.5
5.0	12.2	101.9	12.5	111.4	8.0	85.6
6.0	11.9	101.9	12.5	110.2	8.0	85.5
7.0	11.5	102.2	12.5	109.3	8.0	85.5
8.0	11.3	102.3	12.5	107.3	8.0	85.5
9.0	11.1	102.3	12.2	106.3	8.0	85.6
10.0	10.7	102.3	11.9	104.8	8.0	85.6
11.0	10.2	102.7	11.8	106.9	8.0	85.5
12.0	9.9	102.8	11.7	106.2	8.0	85.6
13.0	9.5	102.7	11.6	106.0	8.0	85.7
14.0	8.6	101.6	10.8	105.1	8.0	85.6
15.0	7.4	102.1	10.5	105.5	8.0	85.5
16.0	7.2	102.2	9.3	102.8	8.0	85.4
17.0	6.7	101.8	8.5	102.3	7.9	85.1
18.0	6.5	101.6	7.5	101.5	7.8	85.1
19.0	6.3	101.3	7.5	102.5	7.8	85.3
20.0	6.2	101.4	7.0	102.2	7.8	85.4
25.0	5.9	101.0	6.4	100.8	7.7	85.2
30.0	5.6	100.5	5.9	100.6	7.6	84.6
35.0	5.4	99.7	5.7	98.3	7.0	81.7
40.0	5.2	93.3	5.4	93.4	5.9	74.9
45.0	-	-	-	-	5.8	38.1

Appendix D.3. Vertical temperature and dissolved oxygen (DO) profiles for Hoktaheen Lake in 8 July, 4 September, and 2 October 2001. Dissolved oxygen levels are shown as percent saturation at the indicated temperature. The first measurement at 0.1 m was taken just below the lake surface. Measurements below 10 m were taken at 5 m intervals.

	8 Jul.		4 Sept.		2 Oct.	
Depth (m)	**Temp (°C)**	**DO (%)**	**Temp (°C)**	**DO (%)**	**Temp (°C)**	**DO (%)**
0.1	-	-	12.8	88.7	-	-
0.5	-	-	12.8	87.4	-	-
1.0	14.3	96.3	12.8	86.6	10.4	95.0
2.0	14.0	96.5	12.8	87.1	10.2	94.0
3.0	13.4	97.9	12.8	87.1	10.1	96.0
4.0	12.2	98.2	12.7	87.2	10.0	93.0
5.0	10.2	97.2	12.0	84.8	10.0	96.0
6.0	8.2	97.1	11.3	83.4	10.0	93.0
7.0	7.6	97.8	8.9	82.2	10.0	94.0
8.0	6.9	97.6	7.7	82.5	10.0	94.0
9.0	6.3	97.6	6.6	83.5	9.9	93.0
10.0	5.8	97.8	5.9	85.1	9.6	92.0
15.0	4.9	98.5	4.6	75.5	5.5	87.0
20.0	4.6	98.7	-	-	5.1	91.0
25.0	4.5	99.1	-	-	5.1	89.0
30.0	4.5	97.8	-	-	5.0	83.0
35.0	4.5	95.7	-	-	5.0	82.0
40.0	4.5	91.7	-	-	-	-

Appendix D.4. Zooplankton density in Gut Bay Lake, 2001.

	Macrozooplankton Density (no·m^{-2})			Seasonal Mean (no·m^{-2})
Station A	**15-May**	**29-Jun**	**2-Oct**	
Ergasilus				0
Epischura				0
Diaptomus				0
Cyclops	841	1,053	2,972	1,622
Bosmina	1,987	3,736	76,753	27,492
Ovig. Bosmina	76	3,940	14,943	6,320
Daphnia l.	229	68	1,613	637
Ovig. Daphnia l.	51	34	0	28
Daphnia g.				0
Holopedium	688	238	425	450
Ovig. Holopedium		204	425	210
Chydorinae	51	204	85	113
Sida crystalina	0			0
Copepod nauplii	3,821	5,196	6,198	5,072
Total				41,944
Station B				
Ergasilus				0
Epischura				0
Diaptomus				0
Cyclops	178	1,019	9,238	3,478
Bosmina	5,069	4,992	52,233	20,765
Ovig. Bosmina	0	4,415	8,762	4,392
Daphnia l.	25	204	611	280
Ovig. Daphnia l.	0	34	68	34
Daphnia g.				0
Holopedium	331	272	408	337
Ovig. Holopedium		136	68	68
Chydorinae	25	272	204	167
Sida crystalina				0
Copepod nauplii	968	4,585	12,905	6,153
Total				35,674

Appendix D.5. Zooplankton size and biomass in Gut Bay Lake, 2001.

	Body Size (mm)			Seasonal Means			
	15 May	29 Jun	2 Oct	Mean Length (mm)	Weighted Length (mm)	Biomass ($mg \cdot m^{-2}$)	Weighted Biomass ($mg \cdot m^{-2}$)
Station A							
Ergasilus							
Epischura							
Diaptomus							
Cyclops	0.46	0.49	0.54	0.50	0.52	1	1
Bosmina	0.30	0.29	0.34	0.31	0.34	24	28
Ovig. Bosmina	0.45	0.29	0.33	0.36	0.32	7	6
Daphnia l.	0.63	0.59	0.59	0.60	0.59	1	1
Ovig. Daphnia l.	0.69	0.73	0.79	0.74	0.71	0.07	0.06
Daphnia g.							
Holopedium	0.33	0.40	0.49	0.41	0.39	1	1
Ovig. Holopedium		0.50	0.55	0.53	0.53	0.50	1
Chydorinae	0.32	0.28	0.28	0.29	0.29	0.09	0.08
Sida crystalina	0.44			0.44	0.44	0	0
Copepod nauplii							
					Total	35	38
Station B							
Ergasilus							
Epischura							
Diaptomus							
Cyclops	0.51	0.51	0.50	0.51	0.50	3	3
Bosmina	0.28	0.33	0.32	0.31	0.32	18	19
Ovig. Bosmina	0.36	0.35	0.34	0.35	0.34	5	5
Daphnia l.	0.64	0.59	0.62	0.62	0.61	0.45	0.45
Ovig. Daphnia l.	0.74	0.74	0.79	0.76	0.77	0.09	0.09
Daphnia g.							
Holopedium	0.35	0.41	0.51	0.42	0.43	0.47	0.49
Ovig. Holopedium		0.52	0.61	0.57	0.55	0.19	0.18
Chydorinae	0.23	0.30	0.28	0.27	0.29	0.11	0.12
Sida crystalina							
Copepod nauplii							
					Total	27	28

Appendix D.6. Zooplankton density in Kook Lake, 2001.

	Macrozooplankton Density ($no \cdot m^{-2}$)				Seasonal Mean
Station A	**16 May**	**7 Jul**	**3 Sep**	**17 Oct**	**($no \cdot m^{-2}$)**
Ergasilus					0
Epischura					0
Diaptomus		1,223	2,038	272	883
Ovig. Diaptomus			272	68	85
Cyclops	25,811	27,509	25,811	12,362	22,873
Ovig. Cyclops	68	917	2,581	747	1,078
Bosmina	1,223	22,415	52,029	32,399	27,017
Ovig. Bosmina	68		272	3,668	1,002
Daphnia l.	10,188	24,147	5,162	3,396	10,723
Ovig. Daphnia	1,630	509		68	552
Daphnia g.					0
Holopedium	611	5,706	9,238	340	3,974
Ovig. Holopedium		1,223	39,395	0	10,155
Chydorinae	0			68	17
Copepod nauplii	4,007	509			1,129
Total					79,488
Station B					
Ergasilus					0
Epischura					0
Diaptomus		7,472	3,396	883	2,938
Ovig. Diaptomus			136	136	68
Cyclops	22,313	18,339	22,143	11,954	18,687
Ovig. Cyclops	102	1,868	2,581	543	1,274
Bosmina	2,394	18,679	79,063	37,358	34,374
Ovig. Bosmina	153	340	408	3,532	1,108
Daphnia l.	7,998	22,924	5,570	2,174	9,667
Ovig. Daphnia	357	849		68	319
Daphnia g.					0
Holopedium	458	23,264	4,347	204	7,068
Ovig. Holopedium		1,528	136	0	416
Chydorinae					0
Copepod nauplii	2,140	509			662
Total					76,580

Appendix D.7. Zooplankton size and biomass in Kook Lake, 2001.

	Body Size (mm)				Seasonal Means			
	16 May	7 Jul	3 Sep	17 Oct	Mean length (mm)	Weighted length (mm)	Biomass ($mg \cdot m^{-2}$)	Weighted biomass ($mg \cdot m^{-2}$)
Station A								
Ergasilus								
Epischura								
Diaptomus		1.09	1.33	1.30	1.24	1.24	7	7
Ovig. Diaptomus			1.35	1.38	1.37	1.36	1	1
Cyclops	0.65	0.90	0.96	0.97	0.87	0.86	61	59
Ovig. Cyclops	1.29	1.22	1.21	1.23	1.24	1.22	6	6
Bosmina	0.40	0.45	0.48	0.54	0.47	0.49	55	61
Ovig. Bosmina	0.57		0.58	0.60	0.58	0.60	3	3
Daphnia l.	0.76	0.90	1.00	0.91	0.89	0.88	39	37
Ovig. Daphnia	0.97	1.12		1.13	1.07	1.01	3	3
Daphnia g.								
Holopedium	0.38	1.09	0.83	0.98	0.82	0.91	28	36
Ovig. Holopedium		1.19	0.97	1.07	1.08	0.98	139	109
Chydorinae	0.26			0.38	0.32	0.38	0	0
Polyphemus								
					Total		342	323
Station B								
Ergasilus								
Epischura								
Diaptomus		0.96	1.28	1.33	1.19	1.08	21	16
Ovig. Diaptomus			1.31	1.33	1.32	1.32	1	1
Cyclops	0.78	0.96	0.92	0.91	0.89	0.89	53	52
Ovig. Cyclops	1.29	1.24	1.23	1.25	1.25	1.24	7	7
Bosmina	0.42	0.49	0.58	0.51	0.50	0.55	81	98
Ovig. Bosmina	0.62	0.69	0.57	0.63	0.63	0.63	4	4
Daphnia l.	0.82	0.84	0.96	0.97	0.90	0.86	35	32
Ovig. Daphnia	1.04	1.15		1.08	1.09	1.12	2	2
Daphnia g.								
Holopedium	0.38	0.88	0.83	0.80	0.72	0.86	36	56
Ovig. Holopedium		1.19	1.02	1.12	1.11	1.18	6	7
Chydorinae								
Polyphemus								
					Total		246	275

Appendix D.8. Zooplankton density in Hoktaheen Lake, 2001.

	Macrozooplankton density (no·m^{-2})			
Station A	**8 Jul**	**4 Sep**	**2 Oct**	**Seasonal Mean (no·m^{-2})**
Ergasilus				0
Epischura				0
Diaptomus				0
Cyclops	119,715	86,432	51,961	86,036
Ovig. Cyclops	1,358	2,377	1,358	1,698
Bosmina	18,679	59,433	7,981	28,698
Ovig. Bosmina	679	2,038	679	1,132
Daphnia l.	1,698	2,547	2,547	2,264
Ovig. Daphnia l.	1,019	1,698	2,547	1,755
Daphnia m.	849	1,019	849	906
Ovig. Daphnia m.		170	0	57
Holopedium				0
Chydorinae				0
Polyphemus				0
Copepod nauplii	9,679	2,717	509	4,302
Total				126,846
Station B				
Ergasilus				0
Epischura				0
Diaptomus				0
Cyclops	275,089	98,998	93,904	155,997
Ovig. Cyclops	3,057	1,019	3,566	2,547
Bosmina	40,754	13,075	42,112	31,980
Ovig. Bosmina	679	3,226	1,358	1,754
Daphnia l.	6,113	4,585	2,887	4,528
Ovig. Daphnia l.	340	679	849	623
Daphnia m.	340	1,698	1,698	1,245
Ovig. Daphnia m.	0			0
Holopedium				0
Chydorinae				0
Polyphemus				0
Copepod nauplii	11,547	4,415	849	5,604
Total				204,279

Appendix D.9. Zooplankton size and biomass in Hoktaheen Lake, 2001.

	Body Size (mm)			Seasonal Means			
	8 Jul	4 Sep	2 Oct	Mean Length (mm)	Weighted Length (mm)	Biomass ($mg \cdot m^{-2}$)	Weighted Biomass ($mg \cdot m^{-2}$)
Station A							
Ergasilus							
Epischura							
Diaptomus							
Cyclops	0.78	0.67	0.81	0.75	0.75	169	167
Ovig. Cyclops	1.09	1.09	1.14	1.11	1.10	8	8
Bosmina	0.46	0.47	0.49	0.47	0.47	60	59
Ovig. Bosmina	0.56	0.57	0.54	0.56	0.56	3	3
Daphnia l.	0.95	0.86	0.91	0.91	0.90	8	8
Ovig. Daphnia l.	1.11	1.01	1.02	1.05	1.03	9	9
Daphnia m.	1.50	1.70	1.76	1.65	1.66	12	12
Ovig. Daphnia m.			2.20	2.20	2.20	1	1
Holopedium							
Chydorinae							
Polyphemus							
Copepod nauplii							
					Total	271	268
Station B							
Ergasilus							
Epischura							
Diaptomus							
Cyclops	0.68	0.66	0.74	0.69	0.69	256	252
Ovig. Cyclops	1.11	1.06	1.13	1.10	1.11	11	12
Bosmina	0.48	0.50	0.42	0.47	0.46	65	62
Ovig. Bosmina	0.58	0.59	0.55	0.57	0.58	6	6
Daphnia l.	0.88	0.78	0.79	0.82	0.83	13	14
Ovig. Daphnia l.	1.04	1.06	1.02	1.04	1.04	3	3
Daphnia m.	1.50	1.56	1.71	1.59	1.62	16	16
Ovig. Daphnia m.	2.02			2.02	2.02	0.00	0.00
Holopedium							
Chydorinae							
Polyphemus							
Copepod nauplii							
					Total	371	365

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